A COMPARATIVE EVALUATION OF

HALODULE WRIGHTII ASCHERS, SPARTINA ALTERNIFLORA

LOISEL AND BARE SAND AS NURSERY HABITATS FOR

JUVENILE CALLINECTES SAPIDUS (RATHBUN)

A Thesis

by

JANET LEA THOMAS

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree
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August 1989

Major Subject: Zoology

A COMPARATIVE EVALUATION OF

HALODULE WRIGHTII ASCHERS, SPARTINA ALTERNIFLORA

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August 1989

ABSTRACT

A Comparative Evaluation of

Halodule wrightii Aschers, Spartina alterniflora Loisel

and Bare Sand as Nursery Habitats for
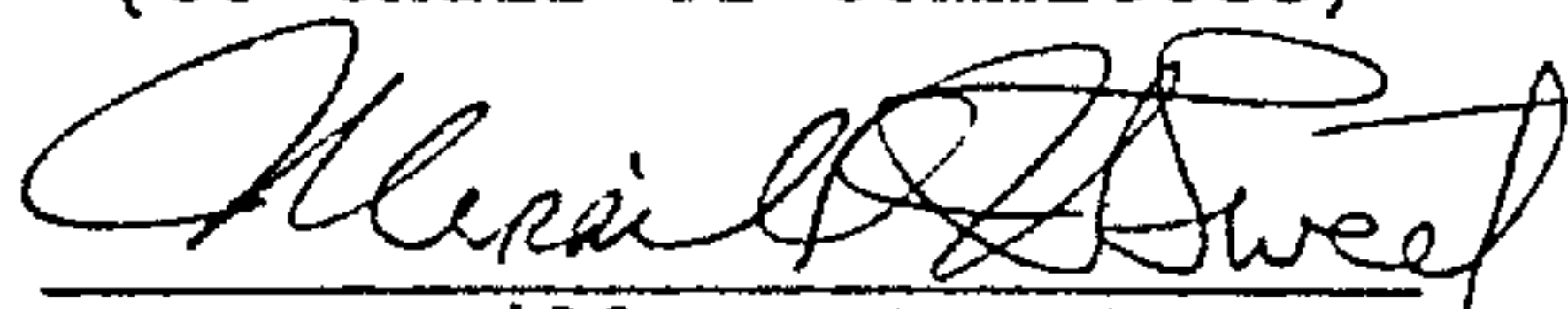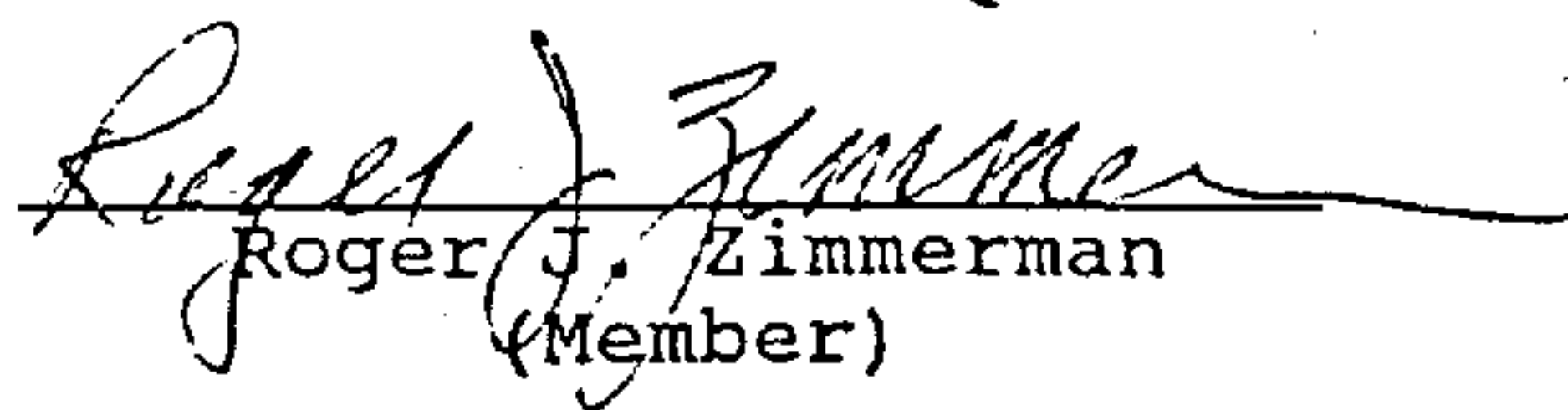
Juvenile Callinectes sapidus (Rathbun). (August 1989)

Janet Lea Thomas, B. S. Eastern Kentucky University

Co-Chairs of Advisory Committee: Dr. Donald E. Harper Jr.
Dr. Merrill H. Sweet

Habitat utilization by economically important species in estuaries has been previously examined through life history studies and faunal surveys. Recently, studies characterizing the food resource and protective functions of estuarine habitats indicate that they serve as valuable nurseries for estuarine dependent species. In this study, laboratory predation experiments were conducted that analyzed differences in food and protective functions provided to juvenile crabs by Spartina alterniflora, Halodule wrightii and bare sand habitats in Christmas Bay, Texas.

Results from feeding experiments showed that small crabs fed upon Halodule epiphytes. Animal foods primarily fed on were amphipods and molluscs. Polychaetous annelids and tanaids were also eaten, but only to a minor extent. During predation experiments, the sand habitat provided the least amount of protection

to juvenile blue crabs during both pinfish and subadult blue crab predation. The salt marsh habitat provided an intermediate degree of protection to juvenile blue crabs during predation by both predators. The seagrass habitat provided the greatest degree of protection to juvenile crabs. This protection varied with grass density and time of day.

Mortalities sustained during pinfish predation were higher during the day than at night in the salt marsh and sand habitats and were similar and low in the seagrass habitats. During subadult blue crab predation, mortalities were higher at night in the seagrass and sand habitats and higher during the day in salt marsh habitats. These results indicate that while juvenile blue crabs are able to feed on numerous foods occurring in each habitat type, their distributions among these habitats may be regulated by the types of predators present and the time of day.

DEDICATION

This thesis is dedicated to my family, whose never ending support has helped me get through graduate school and Eduardo Martinez, for his patience, love, support and assistance. Without it, an August graduation would not have been possible.

ACKNOWLEDGMENT

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INTRODUCTION

Habitat utilization by economically important species in estuaries has been previously examined through life history studies and faunal surveys (Churchill 1921; Pearson 1948; Gunter 1950; Daugherty 1952; Reid 1954; Darnell 1958; Van Engel 1958; Hoese and Jones 1963; O'Gower and Wacasey 1967; More 1969; Briggs and O'Connor 1971). Recently, numerous studies have been directed towards characterizing the food resource and protective functions of estuarine habitats (Virnstein 1978; Heck and Orth 1980a; Coen et al. 1981; Heck and Thoman 1981; Fort 1983; Virnstein et al. 1983; Minello and Zimmerman 1983; Boesch and Turner 1984; Gleason and Zimmerman 1984; Summerson and Peterson 1984; Gleason and Wellington 1988). By providing such benefits, these habitats serve as valuable nurseries for juveniles of estuarine dependent species (Thayer and Phillips 1977; Weinstein 1979; Zimmerman et al. 1984). Studies also indicate that food and protective benefits may vary significantly within and among habitats in estuaries (Virnstein 1978; Minello and Zimmerman 1985; Wilson et al. 1987). In this study, laboratory experiments were conducted to examine variations in food and protective functions provided to juvenile blue crabs (<u>Callinectes</u> <u>sapidus</u> Rathbun) by

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three different estuarine nursery habitats. The results are discussed in context with reviews of blue crab life history and distribution patterns from the literature.

Range and Fishery Importance

Callinectes is a warm-water genus that belongs to the family Portunidae (Norse and Fox-Norse 1982). Norse (1977), states that the latitudinal distribution of Callinectes is limited by summer temperatures (e.g., temperatures required for successful hatching of eggs and survival of larvae). Few species exist where peak temperatures fail to reach 20 °C. The range of Callinectes sapidus extends from Massachusetts Bay, southward to the eastern coast of South America, including the Gulf of Mexico (Williams 1974; Van Den Avyle and Fowler 1984). Blue crabs have been reported as far north as Maine and Nova Scotia after consecutive warm years (Piers 1923; Scattergood et al. 1951), on the Atlantic coast of Europe (Christiansen 1969), and in the Black Sea (Bulgurkov 1968). Populations are also firmly established in the eastern Mediterranean Sea (Halim 1975; Norse and Fox-Norse 1982; Shaheen and Yosef 1979).

Callinectes sapidus supports the largest crab fishery in the United States with 1987 hard crab landings of 197.8 million pounds, valued at $70.8 million dollars (National Marine Fisheries Service 1988). Along the Atlantic coast, highest crab landings were recorded in

the Chesapeake Bay region (Maryland and Virginia) at 75.8 million pounds, followed by the South Atlantic region (North Carolina to Florida) at 47.2 million pounds and the Middle Atlantic region (New York to Delaware) at 7.3 million pounds (Sholar 1982; National Marine Fisheries Service 1988). During 1987, 67.6 million pounds of blue crabs were landed in the Gulf region, with northwestern Gulf states as highest contributors (Perry et al. 1984; National Marine Fisheries Service 1988).

Landings in Texas constitute 22-24% of all Gulf crab landings (Perry et al. 1984; National Marine Fisheries Service 1988). Blue crabs have increased from fourth to second in percent contribution of all fisheries species with highest precent of landings from San Antonio Bay at 30% followed by Aransas Bay at 24% and Galveston Bay at 21% (Hammerschmidt 1982; National Marine Fisheries Service 1988). These statistics are based on commercial sized crabs (100-120 mm carapace width) that are recruited into the fishery 12 months after hatching in southern Atlantic and Gulf waters and 12-20 months after hatching in northern Atlantic waters (Tagatz 1986b; More 1969; Millikin and Williams 1984; Perry et al. 1984).

Life History

The life history of the blue crab has been described for populations occurring in estuarine environments around New Jersey (Kennish et al. 1982), the

Chesapeake Bay (Pearson 1948; Pyle and Cronin 1950; Cargo 1958; Van Engel 1958; Hines et al. 1987), North Carolina (Dudley and Judy 1971), South Carolina (Fischler and Walburg 1962), Florida (Tagatz 1968a; Livingston et al. 1976; Oesterling 1976; Steele 1982), Alabama (Tatum 1982a,b), Mississippi (Perry 1975; Perry and Stuck 1982), Louisiana (Darnell 1959; Adkins 1972; Jaworski 1972), and Texas (Churchill 1921; Daugherty 1952; More 1969; King 1971; Hammerschmidt 1982). Mating occurs in low salinity (10-15 ppt.) estuarine habitats during warm months (May-October) in northern Atlantic waters and year round in southern Atlantic and northern Gulf waters (Churchill 1921; Pearson 1948; Pyle and Cronin 1950; Van Engel 1958; Darnell 1959; Tagatz 1968a). This process involves crabs that have undergone 18-20 molts before becoming sexually mature (Van Engel 1958). Unlike male crabs which continue to grow and mate, females reach a terminal molt, after which growth ceases (Van Engel 1958). Females are then ready to reproduce, and they copulate only once. Sperm are stored by females in seminal receptacles for at least a year to be used during subsequent spawns (Tagatz 1968a).

After mating, male crabs remain in lower salinity estuarine habitats (Dudley and Judy 1971; Hines et al. 1987). Female crabs undertake a long migration to higher salinity areas (>20 ppt.) such as mouths of estuaries or

offshore waters where they will spawn (Churchill 1921;
Cargo 1958; Darnell 1959; Fischler and Walburg 1962;
Tagatz 1968a; More 1969; Tatum 1982a; Hammerschmidt 1982;
Kennish et al. 1982). In contrast to this typical
onshore-offshore migration pattern, Oesterling and Adams
(1982), provided evidence of an along-shore pattern in
Florida's Gulf waters where females migrated up to 499 km
to spawning sites north of their mating grounds.

Spawning seasons in northern Atlantic waters are
brief, and may occur as long as nine months after mating
(Poole 1962; Norse 1977). Conversely, in southern
Atlantic and northern Gulf waters, spawning occurs year
around, as early as two months after mating (Churchill
1921; Daugherty 1952; Tagatz 1968a; Adkins 1972; Tatum
1982b). During this process, approximately 700,000 to
2,000,000 fertilized eggs are extruded onto pleopods
located under the female's abdomen (Van Engel 1958).
This egg mass is initially bright orange in color and is
often referred to as a "berry" or "sponge".
Approximately two weeks after extrusion, embryonic
development is complete, evidenced by a change in egg
mass color from orange to dark brown. This is due to the
absorption of yolk and the development of larval eye
pigments (Van Engel 1958; Tatum 1982a). Eggs are
released from the female's abdomen, hatching occurs and
the first planktonic larval or "zoeal" stages emerge.

Zoeae are exported from spawning areas at the mouths of estuaries via surface currents to higher salinity waters (> 20.1 ppt.) on the continental shelf where development continues (Costlow and Bookhout 1959; Perry et al. 1984; McConaugha, 1988). Seven zoeal molts occur within 31-49 days (Costlow and Bookhout 1959).

"Megalops" larvae emerge from each of the last zoeal molts. This larval stage is characterized by a crab-like appearance, bearing a segmented abdomen that extends beyond the posterior edge of the carapace. Duration of the megalops stage ranges from 6-20 days (Costlow and Bookhout 1959; Sulkin and Van Heukelem 1986). As the main recruitment stage of the blue crab, megalopae undergo behavioral changes in response to light, gravity and pressure which result in their effective utilization of wind driven surface and subsurface tidal currents into bay systems (Perry 1975; Johnson et al. 1984; Sulkin and Epifanio 1986).

Recruitment studies conducted in Delaware Bay and Chesapeake Bay, suggest that megalopae enter shallow water habitats on nighttime spring flood tides and settle out for 1 to 3 days following the full moon (Epifanio et al. 1984; van Montfrans et al. in press). Once in an estuarine environment, megalopae search for vegetated substrates, employing chemical and tactile cues that trigger a transformation into benthic "first crab" or

"young of the year" stages, 2-3mm in carapace width (More 1969; Steele 1982). Larval and "first crab" stages occur predominantly in the late summer and fall in northern Atlantic waters, but are found throughout the year in southern Atlantic and Gulf waters (Churchill 1921; Gunter 1950; Daugherty 1952; Darnell 1959; More 1969; Truesdale 1970; Dudley and Judy 1971; King 1971; Adkins 1972; Perry 1975; Livingston et al. 1976; Daud 1979; Weinstein 1979; Hammerschmidt 1982; Perry and Stuck 1982; Orth and van Montfrans 1987; Wilson et al. in press a.).

Because of numerous inconsistencies between seasonal and annual abundances of megalopae and post-larval crabs, relationships between numbers of larval recruits and post-settlement survivors have not been clearly defined (Perry et al. 1984). Such inconsistencies have been attributed to post-settlement mortality caused by factors such as seasonal and annual changes in the physical environment (ie. water temperature, salinity and dissolved oxygen, water levels and currents), changes in the amount of protective plant structure present and seasonal changes in abundances of predators within shallow water habitats (King 1971; Fonesca et al. 1982; Kennish et al. 1982; Perry and Stuck 1982; Tatum 1982a; Van Engel 1982; Pearson 1948; Zimmerman and Minello 1984; Orth and van Montfrans 1987; Hosking and Lowery 1988; Orth and van Montfrans in press; Thomas et al. in press).

The inability of megalopae to find suitable substrates for settling also effectively reduces the numbers of megalopae and post-settlement juveniles present (Orth and van Montfrans 1987).

Until recently, information pertaining to the general ecology of postsettlement survivors has been limited (Weinstein and Brooks 1983). Interactions between temperature and salinity have been shown to affect their growth rates (Tagatz 1968b; Truesdale 1970; Holland 1971; Cadman and Weinstein 1988). Molting frequency and duration are generally positively correlated with temperature and salinity, and negatively correlated with crab size (Cadman and Weinstein 1988). Cadman and Weinstein (1988), state that there is no significant correlation between molting frequency and crab sex. Optimum growth occurs between 24-30 °C; temperatures above 30 °C cause mortality (Holland 1971; Cadman and Weinstein 1988). Mortalities also increase at salinities at or below 1 ppt (Holland 1971).

Nursery Habitat Utilization

Studies investigating differential habitat utilization by estuarine species in general, report that significantly higher numbers of animals have been found in vegetated habitats when compared to nonvegetated habitats (Santos and Simon 1974; Thayer et al. 1975; Heck and Wetstone 1977; Orth 1977; Heck 1979; Heck and Orth

1980b; Stoner 1980b; Kennish et al. 1982; Penry 1982; Thayer et al. 1982; Lewis and Stoner 1983; Virnstein et al. 1983; Zimmerman et al. 1984; Rader 1984; Zimmerman and Minello 1984). A generally accepted hypothesis is that vegetated habitats serve as valuable nurseries. They provide larger amounts of habitable living space, food resources and protection from predation for juveniles of estuarine-dependent species such as the blue crab than do nonvegetated habitats (Phillips 1960; den Hartog 1967; Herke 1971; McRoy 1973; Hooks et al. 1976; Orth 1976; Kikuchi and Peres 1977; Heck and Orth 1980a; Coen et al. 1981; Lewis and Stoner 1983; Zimmerman et al. 1984; Boesch and Turner 1984; Kneib 1984; Zimmerman and Minello 1984; Minello and Zimmerman 1985). Studies of juvenile blue crab habitat utilization support this hypothesis but also indicate that regional and seasonal differences exist in the quality of food and protection offered by the same general types of habitats (Orth and van Montfrans 1987; Thomas et al. in press; Wilson et al. in press a.).

Regional differences

Orth and van Montfrans (1987), have demonstrated that eelgrass, _Zostera marina_, functions as a primary nursery habitat for juvenile blue crabs in Chesapeake Bay. Penry (1982), found that within the bay, juvenile crabs are most abundant at intermediate depths within _Z._

marina and _Ruppia maritima_ grassbeds of dense, uniform cover. In addition, seagrass beds in the lower end of Chesapeake Bay support higher numbers of juvenile crabs than those in upper reaches of the bay (Heck and Thoman 1984). They attribute this to a lowered probability of recruited individuals reaching upper portions of the bay before attaining maturity. Similar results were found by Bell et al. (1988). In Great Bay, New Jersey, juvenile crabs utilize the macroalga _Ulva lactuca_ as nursery habitat (Wilson et al. in press a.). In both Chesapeake Bay and Great Bay, _Spartina alterniflora_ creeks are also utilized as nurseries but to a lesser extent than seagrasses (Orth and van Montfrans 1987; Wilson et al. in press a.).

In the northwestern Gulf of Mexico, seagrass beds (_Halodule wrightii_), are also preferred nurseries for juvenile crabs (Thomas et al. in press). However, seagrasses are not as prevalent in the northwestern Gulf as salt marsh (_Spartina alterniflora_) habitats. As a result, salt marsh habitats function as alternate juvenile blue crab nurseries (Herke 1971; Thomas et al. in press). Furthermore, juvenile crabs (< 20mm carapace width), are significantly more abundant on flooded marsh surfaces than on subtidal mud or sand (Zimmerman and Minello 1984; Thomas et al. in press).

These regional differences in salt marsh utilization

have been attributed in part to variations in habitat
geomorphology and tidal amplitude (Orth and van Montfrans
1987; Orth and van Montfrans in press; Thomas et al. in
press). Salt marshes in Atlantic coastal estuaries such
as the Chesapeake Bay are characterized by dendritic
intertidal marsh creeks that experience short tidal
inundation periods with daily ranges of 1 meter or
greater (Orth and van Montfrans 1987). Conversely, salt
marsh environments along the northwestern Gulf of Mexico
are reticulated, with stands of vegetation interspersed
among many nonvegetated subtidal pools and creeks. High
rates of soil compaction and subsidence and smaller tidal
ranges (30 cm or more) that occur in this area of the
Gulf result in longer periods of salt marsh inundation
(Hicks et al. 1983; Zimmerman and Minello 1984; Baumann
1987). As a result, these habitats have more habitable
living space and are more accessible for exploitation by
juvenile blue crabs than those occurring along the
Atlantic coast (Thomas et al. in press).

Seasonal differences

Accessibility of intertidal salt marsh habitat is
regulated by seasonal changes in water temperature and
wind direction. This affects water level and,
consequently, juvenile crab distributions. As
temperatures drop and wind directions change, juveniles
burrow into substrates within mid-depth waters where they

overwinter (Penry 1982; Schaffner and Diaz 1988; Thomas et al. in press). During this time period, food availability is limited and little growth occurs. Water levels are reduced which results in some degree of habitat exposure. This reduces the protective cover available to juvenile crabs. Juveniles within Texas salt marshes have been observed buried in substrates between exposed clumps of S. alterniflora (Thomas et al. in press).

With rising temperatures and changes in wind direction, intertidal salt marsh habitats become inundated with water. Along both the Atlantic and Gulf coasts, warm periods are characterized by increased crab feeding activity and growth (Tagatz 1968b; Penry 1982). As dietary opportunists, juvenile crabs are able to utilize molluscs, fishes, crustaceans and plant matter which vary in abundance both spatially and seasonally (Darnell 1958; Tagatz 1968a; Laughlin 1982; Alexander 1986).

Predator activities also increase as water temperatures rise. Surviving juvenile crabs are those that become associated with highly structured areas for protection (Heck and Orth 1980a; Penry 1982). Orth and van Montfrans (1982), state that during laboratory experiments which examined predation by adult blue crabs, juvenile crab mortality was lowest in intermediate

densities of artificial seagrass. Similar results were obtained by Wilson et al. (1987), during juvenile blue crab field tethering experiments in Zostera marina habitats. During periods of low seagrass abundance, juvenile crabs are able to gain refuge from predation in habitats containing Ulva lactuca (Wilson et al. in press b.).

During primary recruitment months (September to December) in Christmas Bay, Texas, small crabs were most abundant in seagrass habitats (Halodule wrightii), followed by salt marsh (Spartina alterniflora) and bare sand habitats (Thomas et al. in press). The comparative value of food and protective benefits of these habitats is not completely understood. The purpose of this study is to assess possible habitat-related differences in these benefits through laboratory food selection and predation experiments. Results from these experiments will be discussed in context with the juvenile crab distrubutions observed in Christmas Bay from July 1984 to June 1985.

Objectives

1. To compare the abundance of juvenile blue crabs with abundance and utilization of certain foods in seagrass, salt marsh and bare sand habitats of Christmas Bay.

2. To compare the degree of protection for juvenile blue crabs in these nursery habitats from day and night

predation by subadult blue crabs <u>Callinectes</u> <u>sapidus</u>, and pinfish, <u>Lagodon</u> <u>rhomboides</u>.

3.   To compare results of this study with nursery utilization patterns of blue crabs reported in the literature.

Because of increased structural complexity and abundance of prey items, the working hypothesis is that food and protection benefits will be greater in seagrass than either salt marsh or sand habitats. The null hypothesis is that there would be no difference.

MATERIALS AND METHODS

A survey of juvenile blue crab distributions in Christmas Bay, Texas (July 1984-June 1985), indicated differential utilization of three nursery habitats (Thomas et al. in press). To determine the mechanisms controlling blue crab utilization of these habitats, experiments were conducted to examine the roles of food and predator influence.

Feeding Experiments

Prior to the actual feeding experiments, potential foods were collected from Christmas Bay nursery habitats and individually fed to juvenile crabs (10mm carapace width). Foods that were tested were epiphytic algae, polychaetous annelids, small mollusks, and peracarid crustaceans. Foods eaten were later analyzed for depletion by crabs in subsequent food selection experiments.

Plant foods

To determine the extent of epiphyte feeding by small crabs, arbitrary samples of _Halodule wrightii_ leaves were obtained from Christmas Bay. Each leaf was washed to remove epifaunal foods such as ostracods, copepods, and small polychaetes, that may have been present. Two 25 mm leaf sections were placed in each of 52 pyrex beakers, containing 150 ml of filtered sea water. All beakers were placed in a water bath.

To ensure that no epifaunal foods remained, leaves within a subsample of 20 randomly selected beakers were examined microscopically. These beakers were then returned to the water bath. Salinity and temperature within each beaker were maintained at 27 o/oo and 25 °C. A fluorescent light ("daylight" bulb), was used to provide a 12 h light/12h dark photoperiod. The beakers were not aerated during the experiment because the photosynthetic action of the seagrass leaves and epiphytes produced enough oxygen to sustain the crabs for up to 18 hours. After 18 hours, 100 ml of sea water was replaced with new water having a dissolved oxygen value of at least 6.5ppm.

Of the 52 beakers, 25 were randomly selected as the "experimental" treatments with crabs and the remaining 27 were designated as "controls" without crabs. Crabs used in this experiment had just been collected from the field. They ranged from 11 to 13 mm in carapace width. The experiment was initiated at 1800 hours during the dark phase of a 12 hour photoperiod. At this time, one juvenile crab was added to each experimental beaker. All beakers were then covered with plastic wrap to prevent water evaporation and crabs from escaping. Dissolved oxygen was monitored (YSI Model 57 oxygen meter) in three to four arbitrarily selected control and experimental treatment beakers every six hours. New beakers were

selected for each subsequent reading. Signs of crab feeding activity such as the presence of fecal material and crab molt exuviae in the bottom of beakers and the depletion of epiphytes as evidenced by bare spots present on the leaves, were recorded after the first 12 hours and then again after 36 hours.

At the end of the 36 hour feeding period, all crabs were removed and measured for new growth. Remaining leaf sections from each beaker were wrapped in aluminum foil and placed in a drying oven (60-70 °C) for one week. Subsequent dry leaf weights were recorded on a microbalance to the nearest 0.1 mg.

Animal foods

To determine the abundance and crab utilization of epifaunal and infaunal foods from nursery habitats, 16 core samples were obtained from each of the seagrass, salt marsh and bare sand habitats. Cores were collected using cylindrical PVC coring tubes (Fig. 1a). Each core, maintained within its core tube constituted a microcosm of its particular habitat (Fig. 1b).

Four microcosms were randomly assigned to each of twelve buckets (Fig. 1c). Each bucket contained 18 liters of aerated sea water (salinity = 27 ppt). All buckets were then placed in a constant temperature water bath maintained at 20 °C. All microcosms were subjected to a 12h light/12h dark photoperiod.

12 cm

8 cm

10 cm

250 Micron
Nitex Screen

A. Perspective View of Corer

Water Level

Vegetation
with Epifauna

Sediment with
Infauna

B. Cross Section of Microcosm

NOT TO SCALE

20 cm

Airline with Airstone

19-Liter Bucket

Water Level

Microcosms

C. Cross Section of 19-Liter Bucket with Microcosms
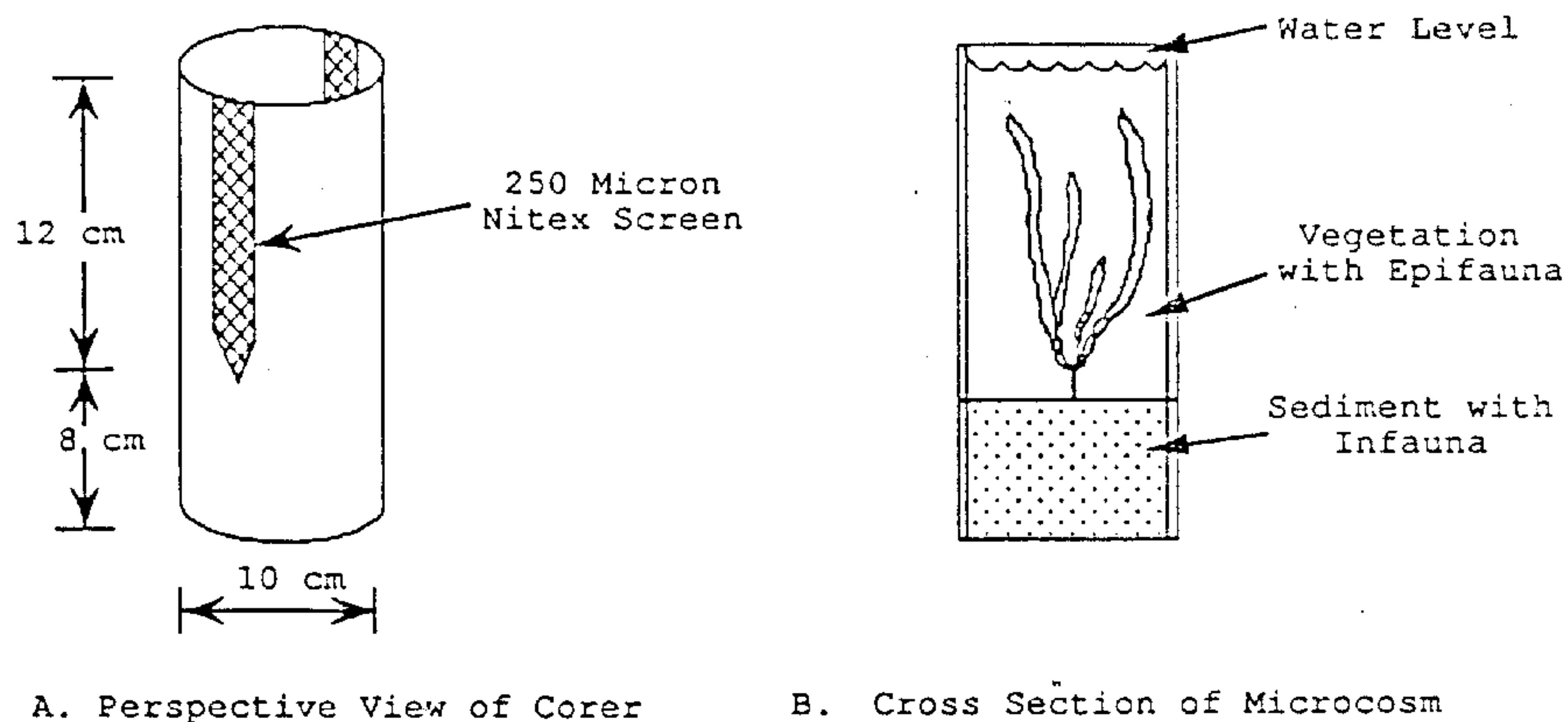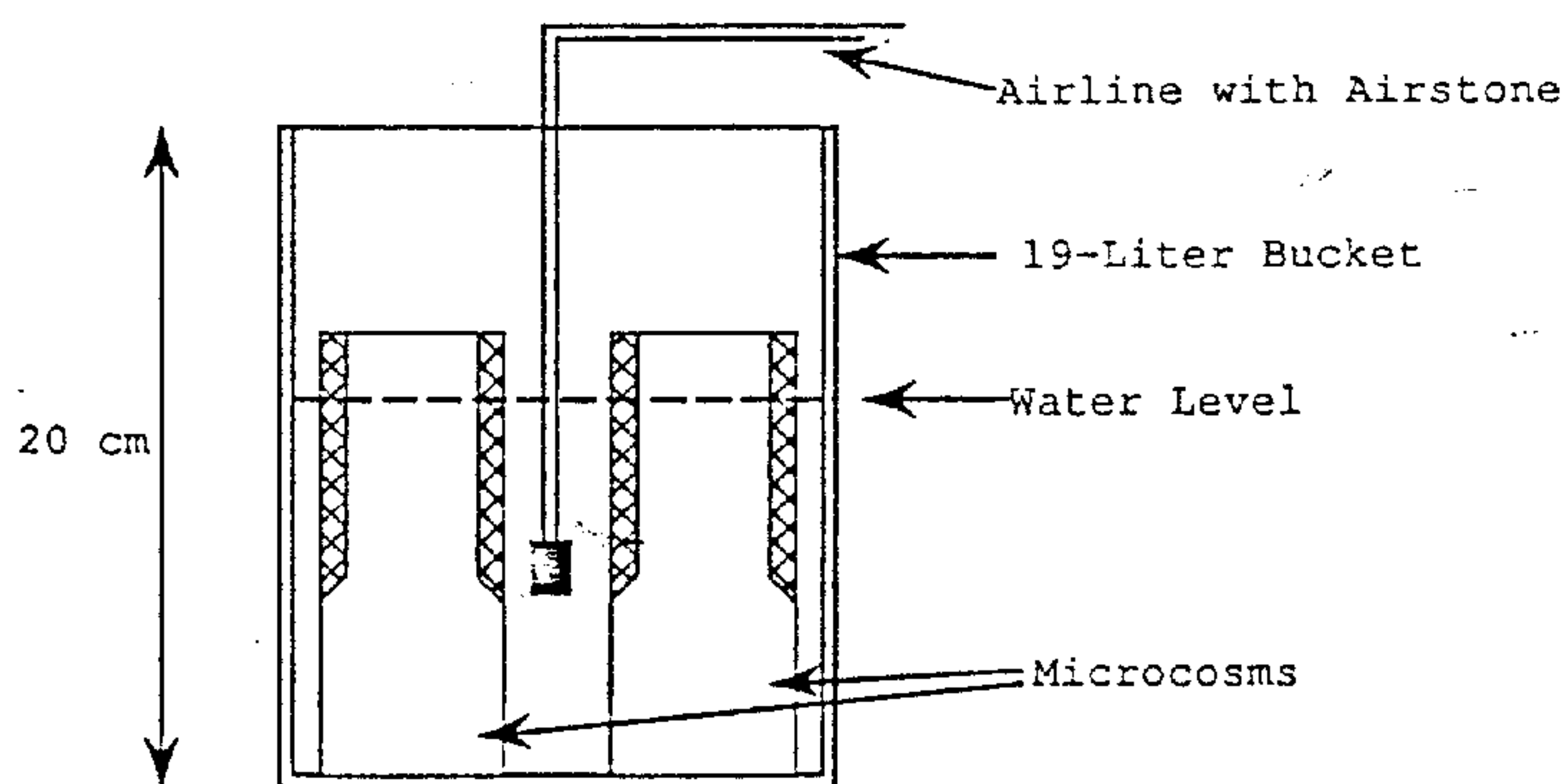
Figure 1. Design and arrangement of microcosms used in juvenile
blue crab feeding experiments.

Eight microcosms from each nursery habitat were randomly selected as "experimental" treatments with crabs and the remaining eight were designated as "controls" without crabs. The experiment was initiated during the light phase of a 12 hour photoperiod. At this time, dissolved oxygen within each of the 12 buckets was 6.6 ppm. Four premeasured juvenile crabs (10 mm carapace width) were then added to each microcosm. Microcosms were then covered with plastic wrap and sealed with rubberbands to prevent crabs from escaping and to eliminate excessive water evaporation.

Temperature, salinity and dissolved oxygen were recorded within each bucket every 12 hours using a hand held thermometer, refractometer and a YSI Model 57 oxygen meter. After a five day feeding period, all crabs were removed. To recover remaining foods, contents within each microcosm were sieved through a 500 micron mesh. The sieved materials were fixed in 5% formalin-rose bengal solution for 24 hours, and then transferred to 70% ethanol to reduce specimen deterioration during long term storage. All animals within each sample were then identified and counted.

Predation Experiments

Predation experiments were designed to assess the protective benefits provided to juvenile crabs by subtidal seagrass (Halodule wrightii), emergent salt

marsh grass (Spartina alterniflora) and sand nursery
habitats. The seagrass and salt marsh grass represented
structured habitats compared to the bare sand habitat
which was nonstructured. Predators used were subadult
Callinectes sapidus (80-100mm carapace width), and
pinfish, Lagodon rhomboides (100-120mm fork length).
These species are abundant during fall recruitment months
and have been documented as important general predators
of macrobenthos (Darnell 1958; Hoese and Jones 1963;
Tagatz 1968a; Adams 1976; Young and Young 1978; Nelson
1979b; Coen et al. 1981; Stoner 1982; Huh 1984; Muncy
1984; Summerson and Peterson 1984; Huh and Kitting
1985;). Although pinfish feeding studies suggest that
fish 100-120mm standard length are largely herbivorous
(Darnell 1958; Carr and Adams 1973; Stoner 1980a; Nelson
1981a), this size was observed consuming juvenile blue
crabs in my preliminary lab experiments (unpub. data).
In addition, this was the most abundant fish species in
the Christmas Bay study area during the blue crab
distribution study conducted from July 1984-June 1985
(National Marine Fisheries Service unpub. data).

The protective benefits of each nursery habitat were
analyzed through six hour predation experiments conducted
during both day (11:00 a.m.-5:00 p.m.) and night (12:00
a.m.-6:00 a.m.) hours. Two day-night trials were
conducted for each predator. Experiments were conducted

in twenty 75-liter aquaria arranged in two rows of ten.

All tanks contained a 5cm layer of sand substrate collected from Christmas Bay or nearby West Bay, Galveston Texas. Preliminary sediment analyses indicated that sand from West Bay had the same grain size as that from Christmas Bay. All sand had been washed and sieved to remove silt and larger objects such as sea shell fragments and worm tubes. The tanks were filled with filtered seawater maintained at 23 °C temperature and 27 ppt salinity. Dissolved oxygen measurements were not taken. Each tank was provided with an external aquarium filter, connected to an air pump. Lighting for each day trial was provided by fluorescent ("daylight") bar lights suspended approximately two meters over the tanks. During night trials, all external light sources were eliminated.

Prior to each trial, five tanks were randomly assigned to each of three habitat treatments: salt marsh, seagrass and bare sand. The salt marsh treatment contained Spartina alterniflora, transplanted from Christmas Bay (Fig. 2a, 2d). To fit in covered aquaria, the Spartina had to be trimmed to an approximate height of 29 cm. It was then washed (to remove excess mud), and arranged within each tank into seven bundles (11 culms per bundle). This resulted in a density of 423 culms/m2, which is similar to densities observed for Spartina
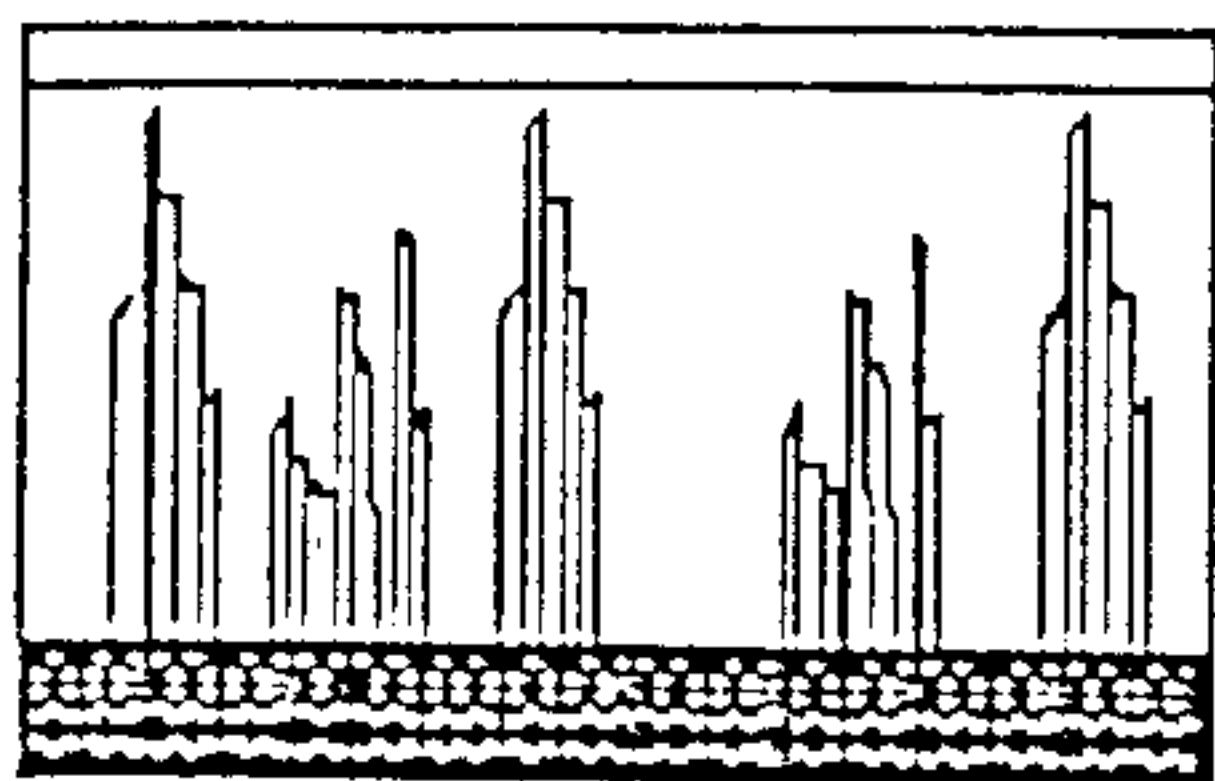
A. Salt Marsh Treatment
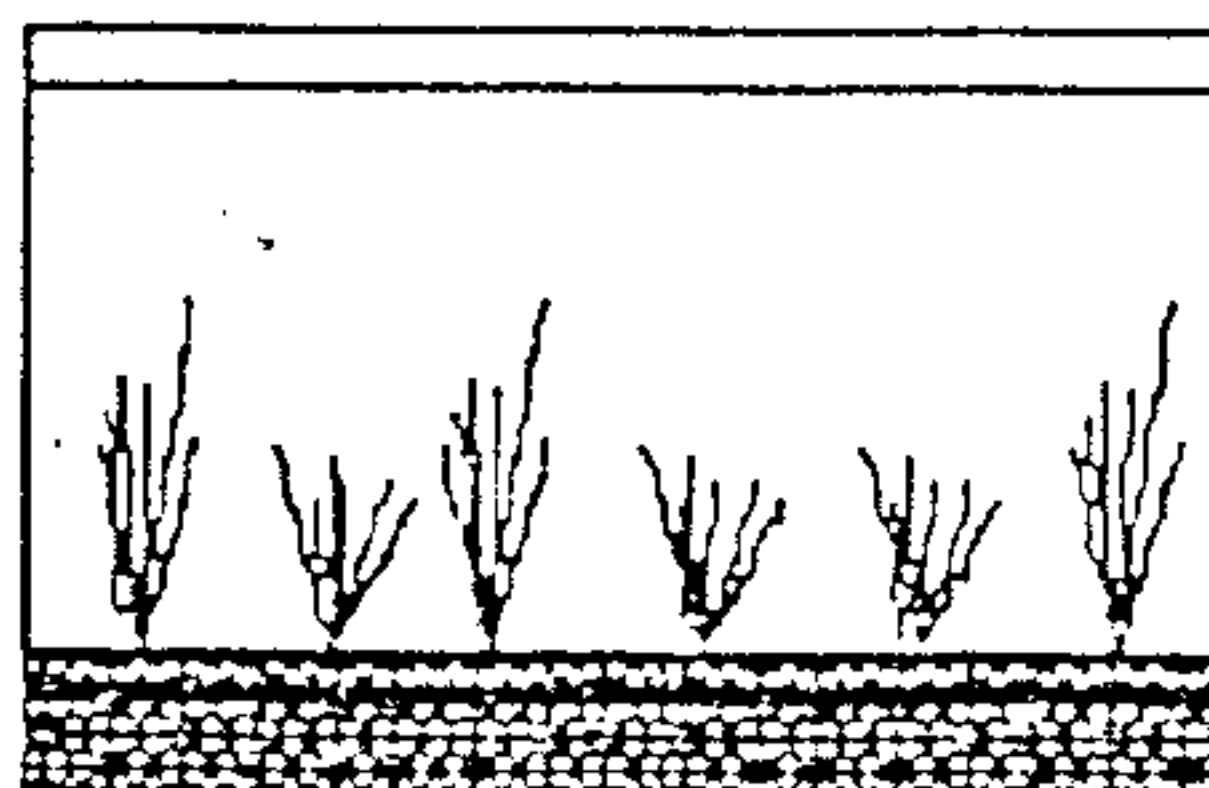
B. Seagrass Treatment
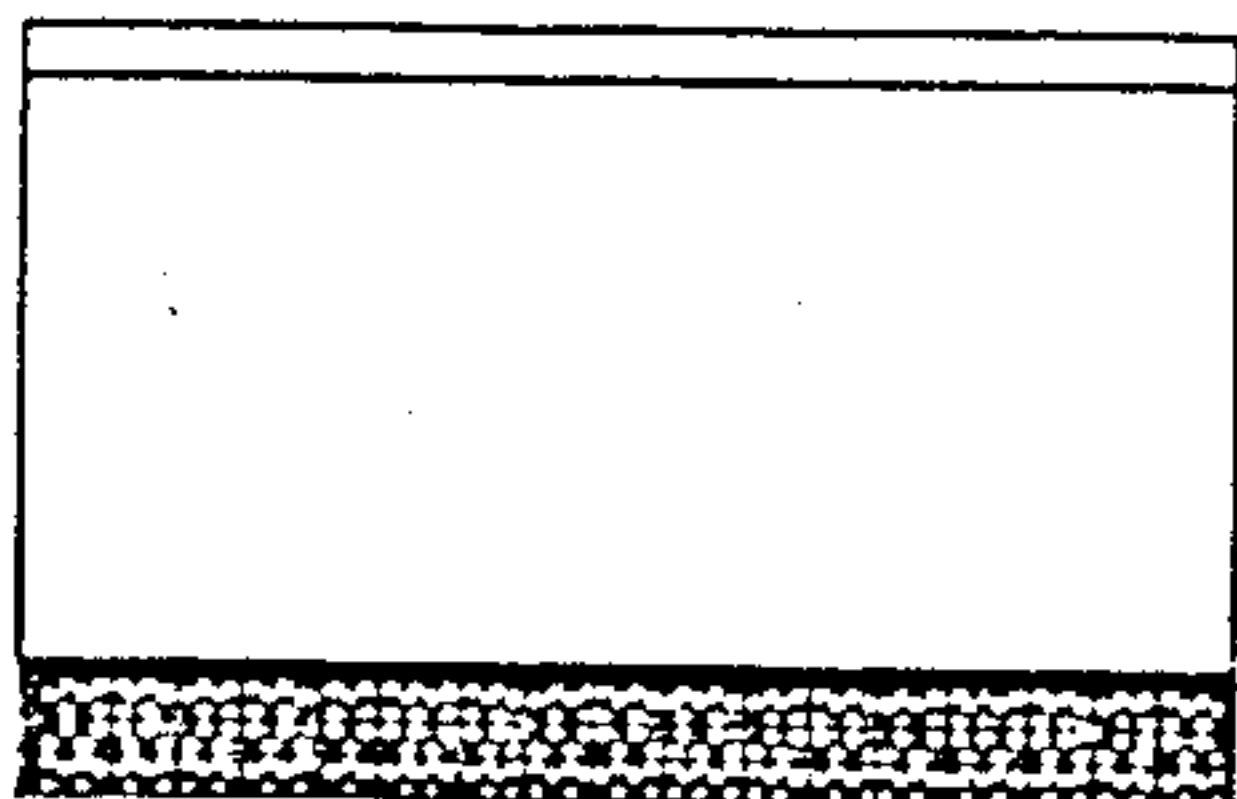
C. Bare Sand Treatment
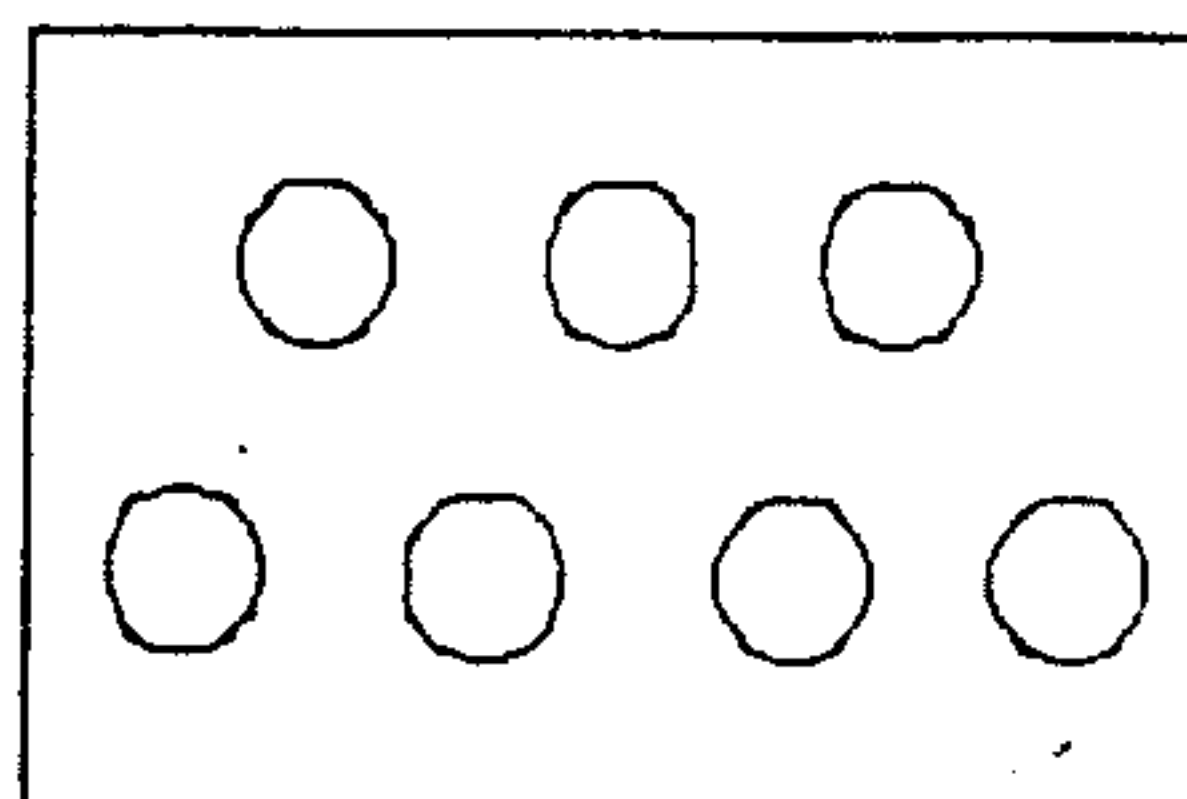
D. Arrangement of vegetation
in marsh and seagrass tanks

Figure 2. Salt marsh, seagrass and bare sand treatment
tanks used during experiments on juvenile blue crab
predation by pinfish and subadult blue crabs.

marshes in Christmas Bay (Thomas et al. in press).

The seagrass treatment tanks contained seven cores of H. wrightii (10cm dia.), also collected from Christmas Bay (Fig. 2b, 2d). Seven additional seagrass cores were randomly collected at this time to estimate leaf densities of the cores used in the treatment tanks. All cores were randomly transplanted into each of the treatment tanks. This approximated the patchy seagrass distribution observed in the field. Unlike the Spartina, Halodule did not maintain its structural integrity afterits core substrate had been washed away. Thus, each transplanted core consisted of three centimeters of sediment and its associated vegetation. All core sediment remained buried under the sand substrate in each tank.

The bare sand treatment contained only sea water and prewashed sand (Fig. 2c). Five additional bare sand tanks were chosen as controls. This decision was based on results obtained from preliminary experiments that were designed to test for cannibalism among juvenile crabs (10mm C.W.) in the absence of predators. These experiments were run under the same conditions as experimental trials with predators. No mortality due to cannibalism or any other natural cause was observed in any of the three habitats. An assumption was then made: in the absence of predators, juvenile blue crab survival

rates were the same in all treatments. Therefore, any one of the three treatments could adequately represent the others as a "control". The sand habitat was then chosen to serve in this capacity.

Predators and prey were collected with a 3.7 meter wide otter trawl and with dip nets from Christmas Bay and West Galveston Bay, Texas. Each predator was then separated into an aerated 19-liter bucket and observed under a 12-hour photoperiod for a minimum of 2-3 days. To allow predators to develop a search image for juvenile blue crabs, they were fed three small crabs each day. Only predators that were active and feeding were assumed healthy enough to be used in predation experiments. Predators were then starved for 24 hours prior to the start of the experiment. At the end of this time period, they were randomly added to each treatment tank, but were confined to plastic mesh cages (Fig. 3).

Three hours before the start of each trial, ten juvenile crabs were randomly added to each tank and allowed to acclimate to experimental conditions. This crab density ($37/m^2$) was similar to those observed in Christmas Bay habitats during fall recruitment months. To minimize predator distraction from animals in adjacent tanks, three sides of each tank were covered with black plastic. Furthermore, the entire experimental apparatus was surrounded by a black plastic curtain to reduce the
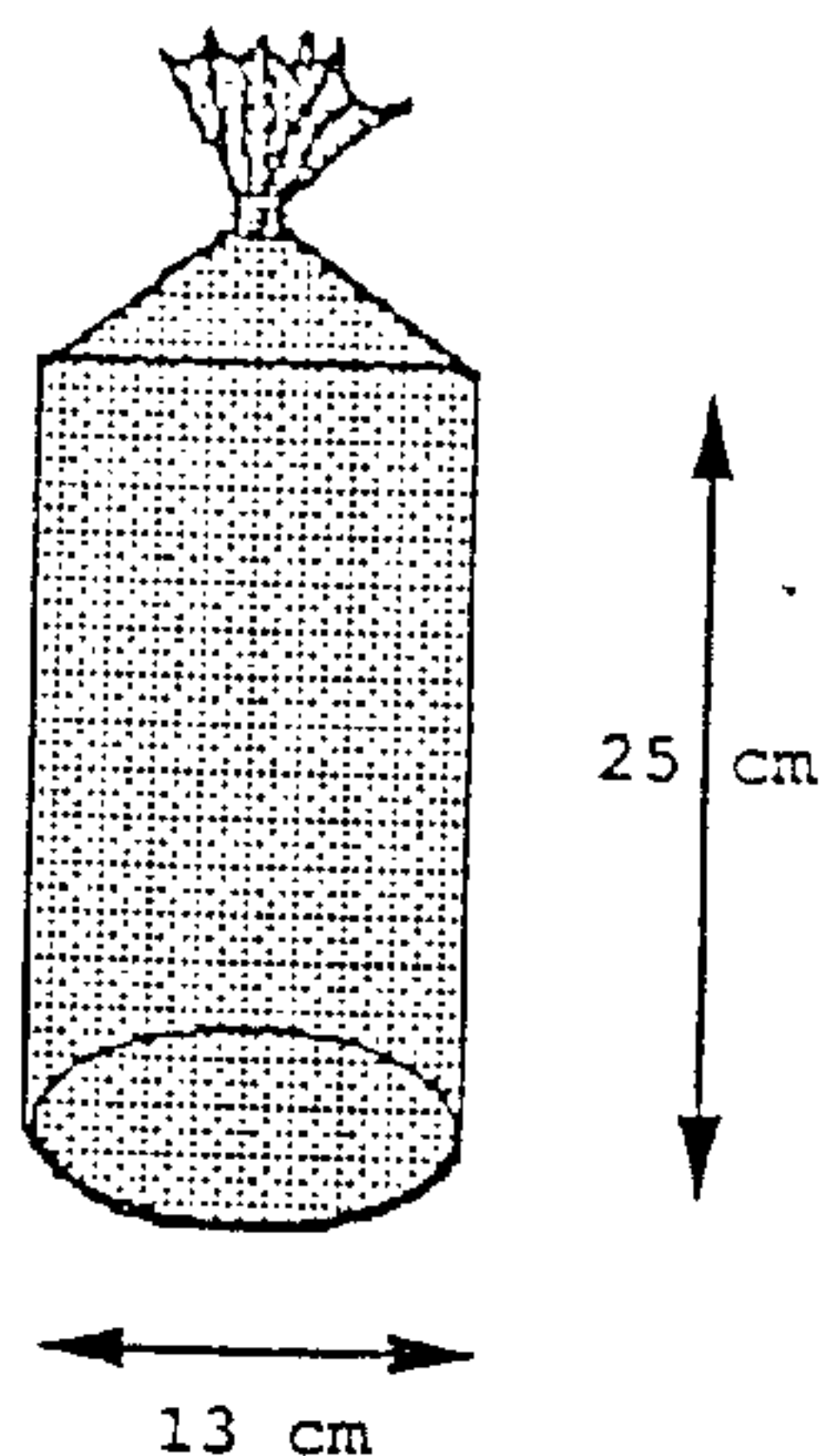
Figure 3. Design of plastic vexar mesh cages used to contain fish or subadult blue crab predators prior to the start of each predation experiment.
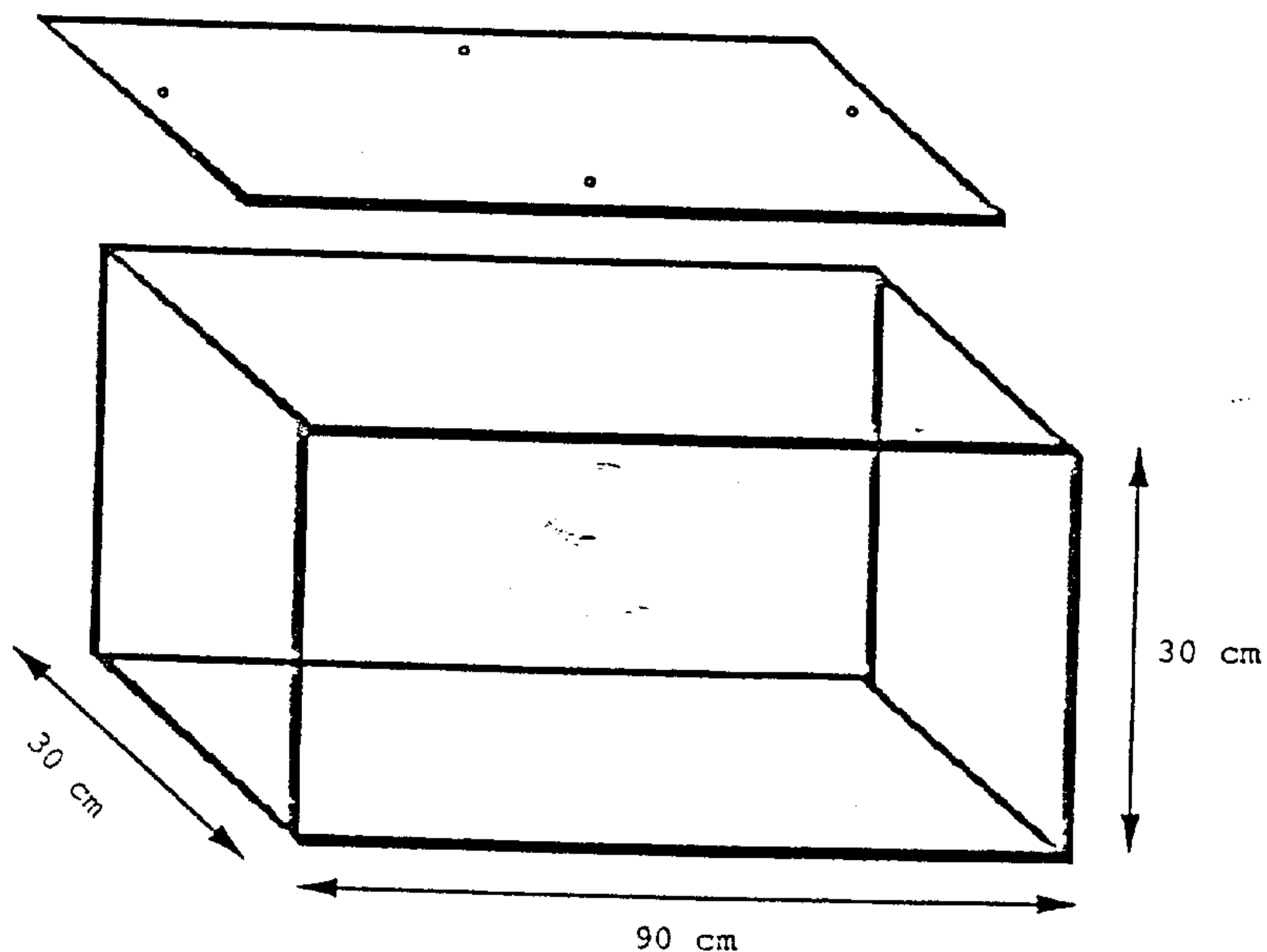
Figure 4. Aquarium and plastic cover used to prevent crabs from escaping during day and night experiments on juvenile blue crab predation by subadult blue crabs.

influence from any outside activity. All aeration and filtration equipment were removed from each tank to insure that juvenile crabs utilized only natural structure as protective cover during the experiment.

Each experiment was initiated when predators were released. Plastic covers were then clamped onto the top of each tank to prevent predators from escaping (Fig. 4). Predators were allowed to feed for six hours. Preliminary experiments indicated that beyond six hours, predators had exhausted the number of prey available. Therefore, comparisons of juvenile crab survival among habitats could not be made. At the end of each trial, all predators were returned to their holding buckets. Remaining juvenile crabs were then removed and tanks were dismantled.

Prior to the start of each new trial, random drawings were made for experimental treatment and control tank assignments. New tanks were then set up and allowed to equilibrate. Each night trial was conducted approximately one day after a day trial, using the same predators but different prey. Prior to the second set of day-night trials, new predators and prey had to be collected.

Statistical Analyses

Data from all experiments were analyzed using the SAS statistical analysis software package for personal

computers (Version 6 1985, SAS Institute, Cary, N. C.).
To assess the impact of juvenile crab feeding activity on
plant material, a one-way Analysis of Variance (ANOVA -
$\alpha = 0.05$) was performed on dry seagrass leaf weights from
control and experimental beakers. Significant reductions
in leaf weights within the experimental beakers were
attributed to consumption of plant material by juvenile
crabs.

Due to a positive linear relationship between the
variances and means of foods recovered from each
microcosm in the animal material feeding experiment, all
data were log transformed. ANOVA and Fisher's Least
Significant Difference (LSD) tests ($\alpha = 0.05$) were then
performed. Differences in natural abundances of food
items among the nursery habitats in control microcosms
were examined first. The impact of feeding by small
crabs was then determined by comparing the abundance of
foods present in control microcosms to those present in
experimental microcosms. A reduction of foods in
experimental microcosms indicated that crab feeding had
occurred. Significant depletions ($\alpha = 0.05$) indicated
selection for certain prey items by juvenile crabs.

Data from both predation experiments were recorded
as mean percent of crabs eaten and as a result, were
arcsin transformed before performing the analyses. To
test for significant differences among habitat type,

between day and night experiments and between the two trials within each experiment, one-way ANOVA ($\alpha = 0.05$) and Fisher's LSD tests were performed. An increase in juvenile crab mortalities within a habitat indicated reduced protection from predation. Seagrass densities were analyzed for significant differences between day and night trials within each predation experiment and between both types of predation experiments (day-night data combined) using ANOVA ($\alpha = 0.05$) and Fisher's LSD tests.

Behavioral Observations

In separate yet similar experiments, qualitative observations of juvenile crab behavior and predator-prey interactions were recorded. Juvenile crab behavior in the absence of predators was assessed through a six hour daylight observation experiment that was conducted in a manner identical to that of previous predation trials. Behaviors were recorded for two minutes while observing the crab nearest the middle of each tank. Observations included, but were not limited to, foraging activities, defense postures and burrowing activities. Five sets of observations were taken in each of three replicate habitat treatment tanks. The first observations were recorded at the start of the experiment, followed by recordings taken after one hour, two hours, four hours and six hours. A similar set of behavioral observations was recorded for both juvenile crabs and pinfish during

day and night predation trials. Juvenile crab behaviors occurring during predation by larger blue crabs were only noted incidentally as predator behaviors were recorded. All night trials were conducted in dim red light.

RESULTS

Feeding Experiments

Plant foods

Throughout the experiment, oxygen in beakers ranged from 6.0 to 9.3 ppm in controls and from 3.3 to 7.2 in experimental beakers (Fig. 5). Visual observations showed that after 18 hours, feeding had occurred. One crab molt was found. Fecal material was present in several treatment beakers in which epiphytic depletion had occurred. After 36 hours, four additional crabs had molted. These crabs had each increased 2-3 mm in carapace width. At this time, leaves in 13 of 25 treatment beakers showed signs of partial epiphytic depletion. Leaves in six other treatment beakers had been completely stripped of epiphytes. In three other treatment beakers, all epiphytic material and part of the seagrass leaves had been consumed. Furthermore, a crab in one treatment beaker had consumed all plant material present. The remaining two treatment beakers showed no signs of feeding activity. ANOVA showed that resultant mean leaf weights from control beakers were significantly higher than mean leaf weights from treatment beakers (Table 1). This quantified the feeding on epiphytes and leaf material that was evident during observation.

Animal foods

Throughout the duration of the experiment,
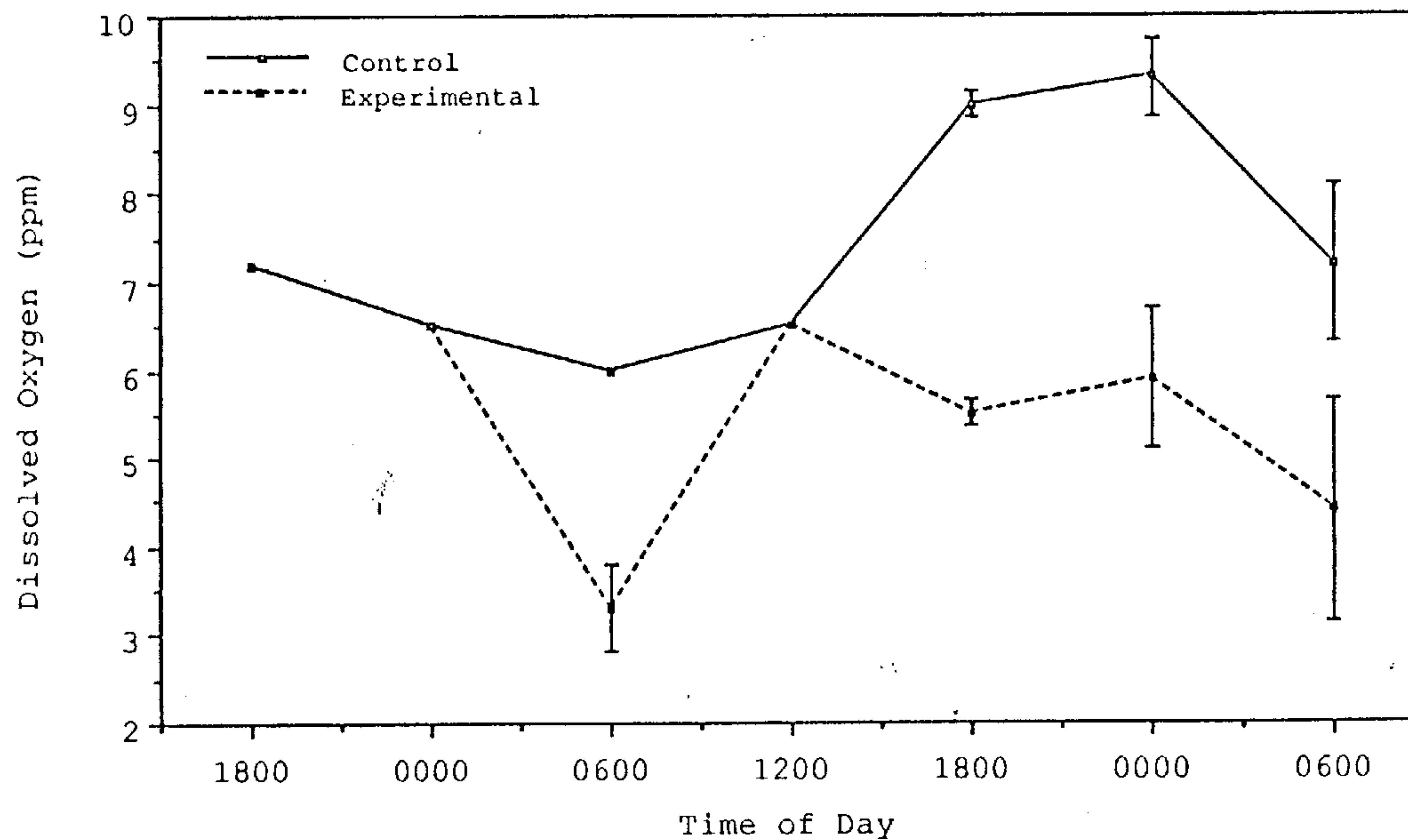
Figure 5. Fluctuations in dissolved oxygen during 36 hours of
Halodule epiphyte depletion by juvenile blue crabs.

Table 1. Depletion of epiphytes and/or associated seagrass
leaves after 36 hours of feeding by juvenile blue crabs;
control vs. experimental dry leaf weights (grams).

Control Weights (n=27)	Experimental Weights (n=25)
0.0092	0.0016
0.0094	0.0082
0.0059	0.0021
0.0084	0.0027
0.0094	0.0053
0.0066	0.0051
0.0079	0.0006
0.0075	0.0016
0.0091	0.0030
0.0062	0.0022
0.0070	0.0039
0.0091	0.0057
0.0100	0.0046
0.0073	0.0029
0.0049	0.0027
0.0104	0.0010
0.0079	0.0025
0.0097	0.0042
0.0077	0.0026
0.0087	0.0007
0.0090	0.0036
0.0095	0.0024
0.0100	0.0052
0.0105	0.0000
0.0104	0.0078
0.0078	
0.0089	

	Control	Experimental
Mean Weight:	0.00846	0.00329
Standard Error:	0.00028	0.00042
P - value:	0.0001	

temperature, salinity and dissolved oxygen ranged from 18.8 °C to 23.5 °C, 25.9 ppt to 27 ppt and 4.6 ppm to 6.9 ppm (Fig. 6). There were three major groups of foods recovered from each microcosm, the majority of which were classified either as annelids (polychaetes and oligochaetes) or peracarids (tanaids, amphipods, isopods, mysids and cumaceans). Molluscs constituted the third group. The remaining animals identified consisted of nemerteans and newly settled blue crabs (2-3mm carapace width), which appeared only incidentally.

The natural mean abundance of all types of animals combined was highest in control microcosms of seagrass, followed by salt marsh and sand habitat types (Fig. 7). ANOVA and Fisher's LSD results are provided in Table 2. Natural annelid abundances were higher in seagrass than either salt marsh or sand habitats. Within each habitat, polychaete species were the most abundant annelids identified. Of the thirty two polychaete species, Streblospio benedicti, Capitella capitata, Mediomastus ambiseta, Neanthes succinea, Heteromastus filiformis, Sabella microphthalma and Chone sp. were the most abundant (Appendix 1). In preliminary observations, the first three species were eaten by juvenile crabs but not the latter four species. For this reason, only the first three species were analyzed as potential foods for juvenile crabs. S. benedicti and M. ambiseta abundances
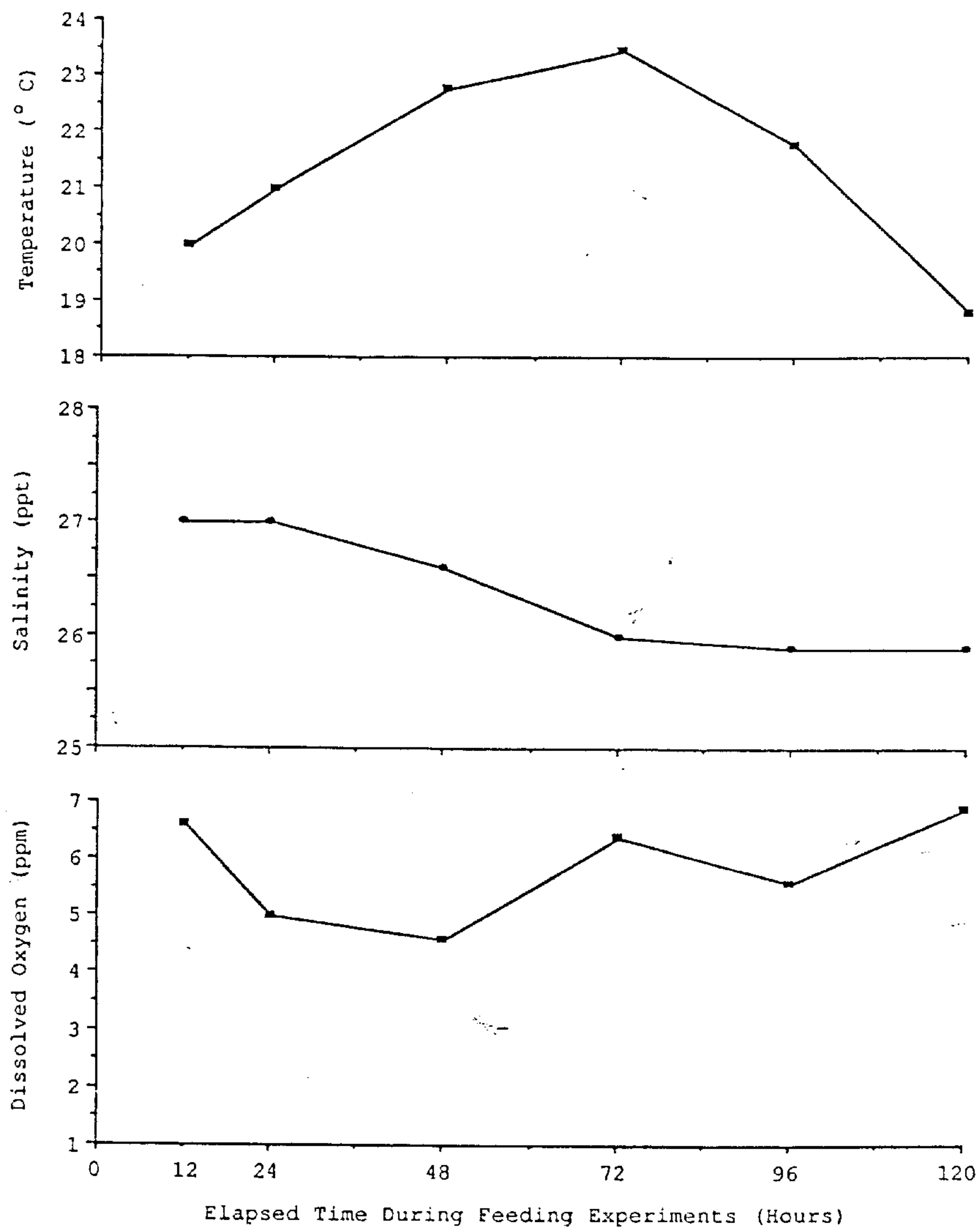
Figure 6. Mean temperature, salinity and dissolved oxygen content during a five day juvenile blue crab feeding experiment.
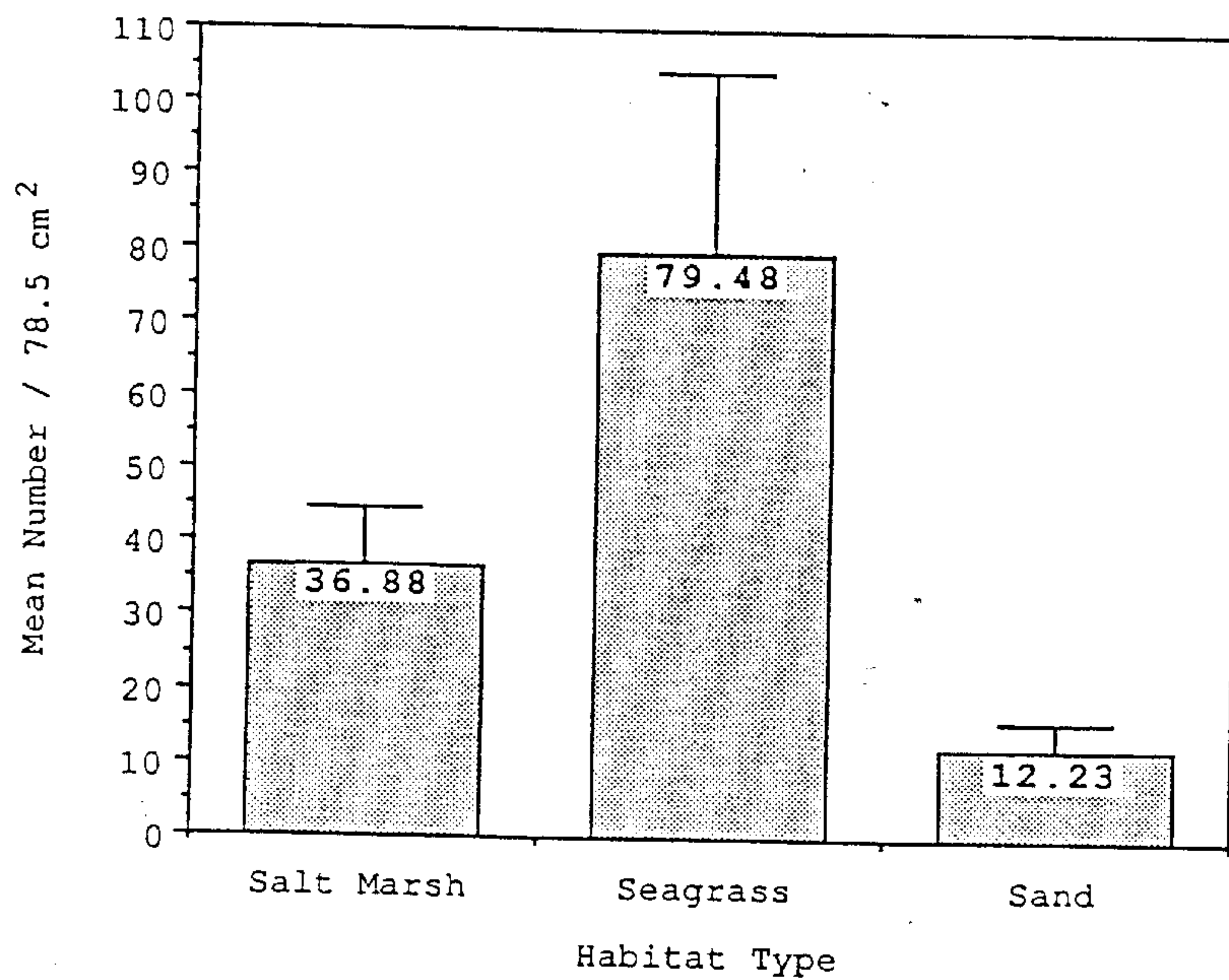
Figure 7. Mean number of prey naturally occurring in salt marsh, seagrass, and sand control microcosms (n=48).

Table 2. Mean natural abundances (mean #/78.5 sq. cm) of food species for juvenile blue crabs in salt marsh, seagrass and sand habitats. Bold print denotes means that are significantly different among habitats within each prey type (ANOVA, LSD p < 0.05).

Habitat Type

Prey	Salt Marsh		Seagrass		Sand		p-values
	Mean	(SE)	Mean	(SE)	Mean	(SE)	
I. Annelids	92.2	(17.5)	**456.6**	(44.4)	65.5	(13.3)	0.0003
A. Polychaetes	90.0	(16.7)	**445.9**	(40.1)	63.0	(12.6)	0.0003
1. *S. benedictii*	51.6	(13.8)	**393.5**	(35.8)	53.8	(11.5)	0.0007
2. *C. capitata*	12.0	(4.9)	14.9	(2.8)	**0.6**	(0.3)	0.0001
3. *M. ambiseta*	1.4	(0.5)	**18.8**	(3.8)	0.3	(0.2)	0.0001
B. Oligochaetes	2.2	(0.9)	10.8	(5.1)	2.5	(1.0)	0.3200
II. Peracarids	**125.4**	(25.1)	**16.1**	(2.8)	**7.0**	(3.2)	0.0001
A. Tanaids	**107.3**	(23.4)	2.1	(0.8)	6.3	(2.8)	0.0001
1. *Hargeria rapax*	**107.3**	(23.4)	2.1	(0.8)	6.3	(2.8)	0.0001
B. Amphipods	18.0	(4.1)	11.3	(2.6)	**0.3**	(0.3)	0.0001
1. *G. mucronatus*	6.5	(3.2)	1.9	(0.7)	**0.0**	(0.0)	0.0098
2. *C. compta*	4.8	(2.1)	3.0	(0.9)	**0.0**	(0.0)	0.0031
3. *Grandidierella* sp.	3.9	(1.0)	3.1	(0.5)	**0.1**	(0.1)	0.0001
4. *Corophium* sp.	**2.5**	(0.7)	0.1	(0.1)	0.0	(0.0)	0.0001
5. *Ampelisca* sp.	0.0	(0.0)	**2.9**	(1.2)	0.1	(0.1)	0.0006
C. Isopods	0.1	(0.1)	**2.0**	(0.3)	0.0	(0.0)	0.0001
1. *E. montosa*	0.1	(0.1)	0.5	(0.3)	0.0	(0.0)	0.1174
2. *Erichsonella* sp.	0.0	(0.0)	**1.5**	(0.4)	0.0	(0.0)	0.0001
III. Molluscs	2.9	(1.1)	3.8	(1.1)	0.9	(0.5)	0.0665
1. *A. papyrium*	0.6	(0.4)	0.9	(0.4)	0.0	(0.0)	0.0582
2. *D. varium*	**1.8**	(0.7)	1.0	(0.5)	0.0	(0.0)	0.0254
3. *Tellina* sp.	0.1	(0.1)	1.3	(1.0)	1.4	(1.3)	0.0562

were higher in seagrass than either salt marsh or sand. Abundances of C. capitata were similar in both seagrass and salt marsh habitats, and lower in sand. Oligochaetes comprised the remaining annelids identified. Although no significant differences were detected, their numbers were highest in seagrass, followed by sand and salt marsh habitats.

Peracarid abundances in each habitat were significantly different. Highest abundances occurred in the salt marsh habitat, followed by seagrass and sand habitats. Within the peracarid group, tanaids (Hargeria rapax), were the most abundant, followed by amphipods and isopods. Cumaceans and mysids were only incidentally recorded. Within the three habitats, H. rapax abundance was higher in salt marsh than sand or seagrass habitats. Amphipod abundances were similar in salt marsh and seagrass habitats and lower in sand habitats. Of the seven species identified, the most common amphipod species present were Gammarus mucronatus, Cymadusa compta, Grandidierella sp., Corophium sp., and Ampelisca sp. Abundances of G. mucronatus, C. compta and Grandidierella sp. were similar between salt marsh and seagrass habitats and lower in sand habitats. Corophium sp. abundances were higher in salt marsh habitats than in seagrass habitats and were nonexistent in sand habitats. Ampelisca sp. abundances were higher in seagrass habitats

than in sand habitats. They were nonexistent in salt marsh habitats.

Isopods as a group were low in abundance. They were more abundant in seagrass when compared to salt marsh, and were nonexistent in sand. Of the two species identified,*Erichsonella* sp. was most abundant. Highest numbers of individuals occurred in the seagrass habitat. They were nonexistent in the salt marsh and sand habitats. Abundances of *E. montosa* were also higher in seagrass than in salt marsh, but not significantly. None were present in sand.

Abundances of molluscs as a group were similar in seagrass and salt marsh habitats and lower in sand habitats, although not significantly. Of the 14 species identified, the most abundant were *Amygdalum papyrium*, *Diastoma varium*, and *Tellina* sp. (Appendix 1). *A. papyrium* abundances were similar in the seagrass and salt marsh habitat. *D. varium* abundances were higher in salt marsh than in seagrass. Neither *A. papyrium* nor *D. varium* were present in the sand habitat. *Tellina* sp. abundances were highest in sand habitats followed by seagrass and salt marsh habitats, but not significantly.

ANOVA and Fisher's LSD analyses of feeding by juvenile crabs are shown in Table 3 and 4. As a group, annelids were eaten, but were not significantly depleted in any of the three nursery habitats. Each of the three

Table 3. Juvenile blue crab feeding in salt marsh, seagrass and sand microcosms (mean number/78.5 sq. cm) over five days (experimental treatments with 4 crabs; controls without crabs). Bold print denotes a significant depletion in experimental treatment within a habitat type.

Habitat Type

Prey	Salt Marsh Control Mean (SE)	Salt Marsh Experimental Mean (SE)	Seagrass Control Mean (SE)	Seagrass Experimental Mean (SE)	Sand Control Mean (SE)	Sand Experimental Mean (SE)
I. Annelida	92.3 (17.5)	92.4 (12.3)	456.6 (44.4)	404.5 (24.3)	65.5 (13.3)	79.6 (16.0)
A. Polychaetes	90.0 (16.7)	86.8 (10.4)	445.9 (40.1)	397.1 (24.4)	63.0 (12.6)	73.3 (16.8)
1. *S. benedictii*	51.6 (13.8)	37.6 (6.8)	393.5 (35.8)	359.0 (20.4)	53.8 (11.5)	63.5 (16.0)
2. *C. capitata*	12.0 (4.9)	8.3 (1.6)	14.9 (2.8)	8.9 (1.4)	0.6 (0.3)	0.8 (0.4)
3. *M. ambiseta*	1.4 (0.5)	0.6 (0.4)	18.8 (3.8)	12.1 (3.4)	0.3 (0.2)	0.9 (0.4)
B. Oligochaetes	2.3 (0.9)	5.6 (3.3)	10.8 (5.1)	7.4 (2.3)	2.5 (1.0)	6.4 (3.6)
II. Peracarids	125.4 (25.1)	**46.4** (11.4)	16.1 (2.8)	**6.9** (1.5)	7.0 (3.2)	9.3 (2.4)
A. Tanaids	107.3 (23.4)	40.5 (10.0)	2.1 (0.8)	2.1 (1.1)	6.3 (2.8)	8.4 (2.6)
1. *Hargeria rapax*	107.3 (23.4)	40.5 (10.0)	2.1 (0.8)	2.1 (1.1)	6.3 (2.8)	8.4 (2.6)
B. Amphipods	18.0 (4.1)	**5.9** (1.9)	11.3 (2.6)	**4.4** (1.1)	0.3 (0.3)	0.8 (0.5)
1. *G. mucronatus*	6.5 (3.2)	0.9 (0.7)	1.9 (0.7)	**0.4** (0.3)	0.0 (0.0)	0.0 (0.0)
2. *C. compta*	4.8 (2.1)	**0.6** (0.3)	3.0 (0.9)	0.9 (0.4)	0.0 (0.0)	0.0 (0.0)
3. *Grandidierella* sp.	3.9 (1.0)	2.6 (0.8)	3.1 (0.5)	**0.8** (0.4)	0.1 (0.1)	0.1 (0.1)
4. *Corophium* sp.	2.5 (0.7)	1.4 (0.6)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)
5. *Ampelisca* sp.	0.0 (0.0)	0.3 (0.2)	2.9 (1.2)	2.4 (0.8)	0.1 (0.1)	0.5 (0.5)
C. Isopods	0.1 (0.1)	0.0 (0.0)	2.0 (0.3)	**0.4** (0.3)	0.0 (0.0)	0.1 (0.1)
1. *E. montosa*	0.1 (0.1)	0.0 (0.0)	0.5 (0.3)	0.1 (0.1)	0.0 (0.0)	0.1 (0.1)
2. *Erichsonella* sp.	0.0 (0.0)	0.0 (0.0)	1.5 (0.4)	**0.3** (0.3)	0.0 (0.0)	0.0 (0.0)
III. Mollusca	2.9 (1.1)	1.8 (0.7)	3.8 (1.1)	**1.3** (0.5)	0.9 (0.5)	0.4 (0.2)
1. *A. papyrium*	0.6 (0.4)	0.3 (0.2)	0.9 (0.4)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
2. *D. varium*	1.8 (0.7)	1.1 (0.6)	1.0 (0.5)	0.4 (0.2)	0.0 (0.0)	0.0 (0.0)
3. *Tellina* sp.	0.1 (0.1)	0.0 (0.0)	1.3 (1.0)	0.3 (0.2)	1.4 (1.3)	0.0 (0.0)

Table 4. Fisher's LSD p-values for juvenile blue crab feeding results listed in Table 3. Dashed lines indicate no tests performed due to absence of animals in habitat.

Habitat Type

Prev	Salt Marsh	Seagrass	Sand
I. Annelids	0.7003	0.3632	0.5063
A. Polychaetes	0.7962	0.3550	0.6913
1. *S. benedictii*	0.8733	0.4700	0.9138
2. *C. capitata*	0.9138	0.0823	0.9016
3. *M. ambiseta*	0.8388	0.1796	0.1956
B. Oligochaetes	0.3283	0.8668	0.3118
II. Peracarids	0.0394	0.0185	0.3245
A. Tanaids	0.1396	0.7610	0.4479
1. *Hargeria rapax*	0.1396	0.7610	0.4479
B. Amphipods	0.0082	0.0334	0.3580
1. *G. mucronatus*	0.0553	0.0493	---
2. *C. compta*	0.0343	0.0572	---
3. *Grandidierella* sp.	0.3322	0.0015	1.0000
4. *Corophium* sp.	0.2644	0.3343	0.3343
5. *Ampelisca* sp.	0.1489	0.7745	0.6076
C. Isopods	0.3343	0.0004	0.3343
1. *E. montosa*	0.3343	0.2337	0.3343
2. *Erichsonella* sp.	---	0.0122	---
III. Molluscs	0.6215	0.0471	0.5325
1. *A. papyrium*	0.4384	0.0096	---
2. *D. varium*	0.4628	0.3190	---
3. *Tellina* sp.	0.3343	0.4531	0.1621

polychaete species were reduced in abundance in the salt marsh and seagrass habitats. Oligochaetes were reduced in abundance only in the seagrass habitat. The distributions observed in the annelid group could have been the result of natural variability occurring among the three habitats. In contrast, significant depletion did occur within the peracarids in salt marsh and seagrass habitats. The tanaid, $\underline{H}$. $\underline{rapax}$ was consumed in the salt marsh habitat, but was not significantly depleted at the $\alpha = 0.05$ level. Of the most abundant amphipods, $\underline{G}$. $\underline{mucronatus}$ and $\underline{Grandidierella}$ sp., $\underline{C}$. $\underline{compta}$ and $\underline{Corophium}$ sp. were all reduced in abundance in both vegetated habitats. $\underline{G}$. $\underline{mucronatus}$ was depleted in the seagrass habitat ($\alpha = 0.049$) and the salt marsh habitat ($\alpha = 0.055$). $\underline{Grandidierella}$ sp. was eaten in both habitats but only significantly depleted in the seagrass habitat. $\underline{C}$. $\underline{compta}$ was depleted in the salt marsh habitat ($\alpha = 0.034$) and in the seagrass habitat ($\alpha = 0.057$). $\underline{Corophium}$ sp. was reduced in abundance in both vegetated habitats but not significantly. $\underline{Ampelisca}$ sp. was reduced in abundance in the seagrass habitat, but not significantly depleted. Amphipod abundances were either unchanged or nonexistant in the sand habitat. Distribution patterns observed for $\underline{Corophium}$ sp. and $\underline{Ampelisca}$ sp. (as well as others), could have been the result of natural variability occurring among the three

habitats. The isopod, E. montosa was low in abundance and variable in its distribution. Any consumption occurring in either vegetated habitat would have been hard to detect. Erichsonella sp. was also low in abundance but was depleted in the seagrass habitat.

A. papyrium, D. varium and Tellina sp. were generally low in abundance. Reductions in their numbers did occur in both vegetated habitats. Tellina sp. was also reduced in abundance in the sand habitat. These differences may have been related to crab feeding or to natural variability in their distributions among the habitats. Significant depletions of A. papyrium did occur in the seagrass habitat. Both A. papyrium and D. varium were nonexistant in the sand habitat.

Of the 96 crabs used in experimental microcosms, 51 had increased in carapace width by 1-2 mm or more at the end of the experiment. Of the remaining 45, 32 stayed the same size. Unfortunately, 13 additional crabs had escaped from microcosms into outer buckets.

Predation Experiment Results

Pinfish

During the first set of day-night trials, temperature and salinity in all of the tanks averaged 27 °C and 30 ppt. Temperature and salinity in all tanks during the second set of trials were 23 °C and 26.8 ppt. ANOVA results indicated that no significant differences

in juvenile crab mortality occurred between trials of
either day or night experiments (Table 5a). Therefore,
data within each set of trials were combined for the
remaining analyses. There was a significant effect of
habitat type (Table 5a). Highest percent of mortalities
(day and night data combined) occurred in sand treatments
followed by salt marsh and seagrass treatments (Table 6,
Fig. 8). Mortalities in the sand habitats were
significantly different from salt marsh and seagrass
treatments (Table 6). Time had no significant effect on
crab mortality (Table 5a). Juvenile crab mortalities
sustained in the sand and salt marsh treatments during
day predation were higher than those occurring at night,
but not significantly (Table 7, Fig. 9). Mortalities
occurring in the seagrass treatment during both day and
night experiments were low and equivalent (Table 7, Fig.
9). No significant interactions occurred between time
and habitat, trial and habitat or time and trial (Table
5a).

Blue crab

Temperature and salinity values during the first set
of day-night trials were 23 °C and 26 ppt respectively.
During the second set of trials, temperature and salinity
values were 20 °C and 26 ppt. Analysis of variance
indicates that no significant differences in mortality
occurred between trials of either day or night

Table 5.   ANOVA results from predation experiments with
   A) pinfish and B) subadult blue crabs using the
   mean percent of juvenile blue crabs eaten within
   each treatment as the observation.

A. Pinfish predation.

Source of Error	df	Sum of Squares	F	p-value
HABITAT	3	4.96	22.2	< 0.001
TIME	1	0.12	1.7	0.207
TRIAL	1	0.05	0.7	0.421
TIME*HABITAT	3	0.13	0.6	0.629
TRIAL*HABITAT	3	0.17	0.8	0.528
TRIAL*TIME	1	0.01	0.2	0.668
ERROR	67	5.99		

B. Subadult Blue Crab predation.

Source of Error	df	Sum of Squares	F	p-value
HABITAT	3	3.11	11.6	< 0.001
TIME	1	0.55	6.1	0.016
TRIAL	1	0.04	0.4	0.521
TIME*HABITAT	3	1.37	5.1	0.003
TRIAL*HABITAT	3	0.48	1.8	0.158
TRIAL*TIME	1	0.22	2.5	0.121
ERROR	67	4.99		

Table 6. Mean and standard error of juvenile blue crabs eaten (percent mortality in parentheses), day and night results combined, in salt marsh, seagrass and sand habitats during predation by pinfish and subadult blue crabs.

		Salt Marsh			Seagrass			Sand			
Predator	N	Mean	SE	%	Mean	SE	%	Mean	SE		%
Pinfish	20	2.3	0.4	(23)	1.1	0.4	(11)	6.3	1.0	*	(63)
Blue Crab	20	2.4	0.8	(24)	2.8	0.6	(28)	4.7	0.6	*	(47)

* - indicates significance at $p < 0.05$.
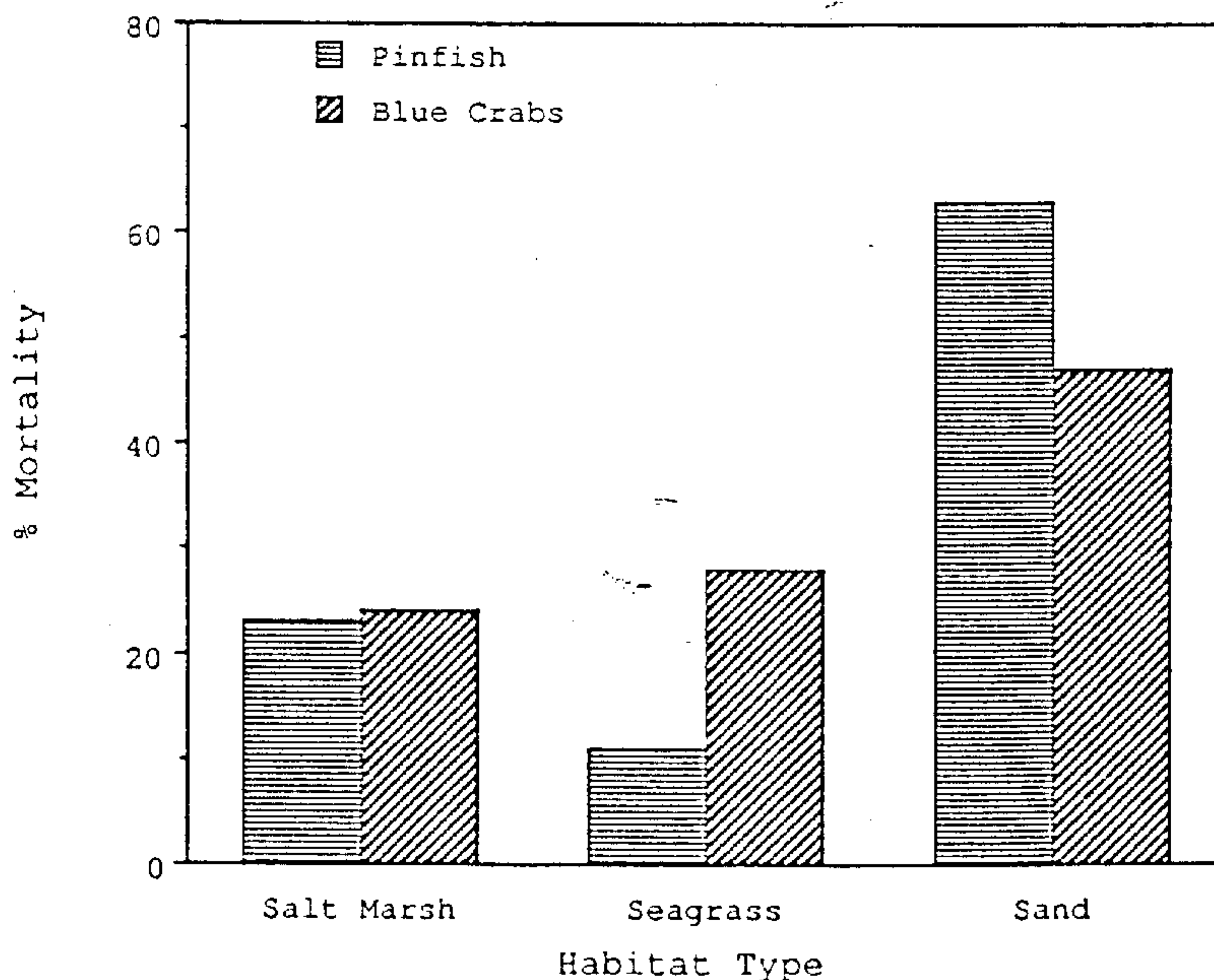
Figure 8. Mortality of juvenile blue crabs in salt marsh, seagrass and sand habitats during predation by pinfish and subadult blue crabs.

Table 7. Juvenile blue crab mortalities during day and night predation by pinfish. Percent mortalities given in parentheses.

Trial	N	Salt Marsh			Seagrass			Sand		
		Mean	SE	%	Mean	SE	%	Mean	SE	%
Day	10	2.6	0.7	(26)	1.1	0.6	(11)	6.3	1.0	(63)
Night	10	2.0	0.6	(20)	1.1	0.5	(11)	4.9	1.2	(49)
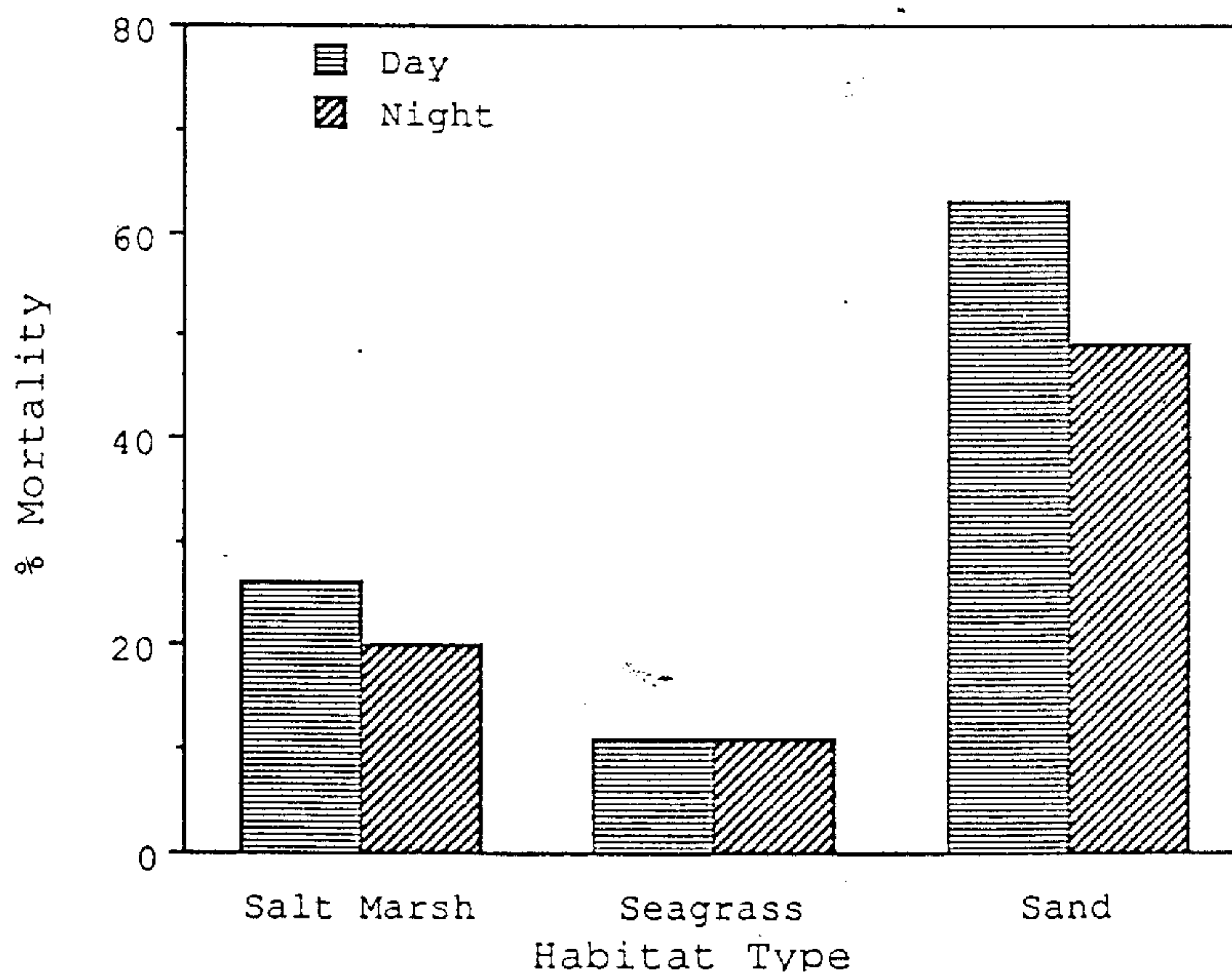
Figure 9. Predation by pinfish on juvenile blue crabs in salt marsh, seagrass and sand habitats between day and night predation experiments.

experiments (Table 5b). Therefore, data within each set of trials were combined for the remaining analyses. There was a significant interactive effect of habitat and time on juvenile crab mortality (Table 5b). Highest percent of mortalities (day and night experimental data combined) highest mortalities occurred in sand treatments followed by seagrass and salt marsh treatments (Table 6, Fig. 8). In the seagrass and sand treatments, mortalities sustained by juvenile blue crabs were significantly higher at night than during the day (Table 8, Fig. 10). Conversely, mortalities sustained in the salt marsh were lower at night than during the day, but not significantly (Table 8, Fig. 10).

Densities of seagrass used during pinfish and blue crab predation experiments are listed in Table 9. ANOVA and Fisher's LSD tests indicate that seagrass leaf densities (mean # leaves/core) in pinfish trials (day and night data combined) were significantly higher than those used during blue crab predation trials ($\alpha = 0.0001$). However, no significant differences in seagrass densities were found between day and night trials for either predator species.

Behavioral Observations

Juvenile blue crab

Observations of juvenile crab behavior within salt marsh seagrass and sand habitats in the absence of

Table 8. Juvenile blue crab mortalities during day and night predation
by subadult blue crabs. Percent mortalities given in parentheses.

		Salt Marsh			Seagrass			Sand		
Trial	N	Mean	SE	%	Mean	SE	%	Mean	SE	%
Day	10	3.1	1.3	(31)	1.1	0.5	(11)	3.1	0.7	(31)
Night	10	1.8	0.8	(18)	4.5	0.7	* (45)	6.4	0.8	* (64)

* - indicates significance at $p < 0.05$.
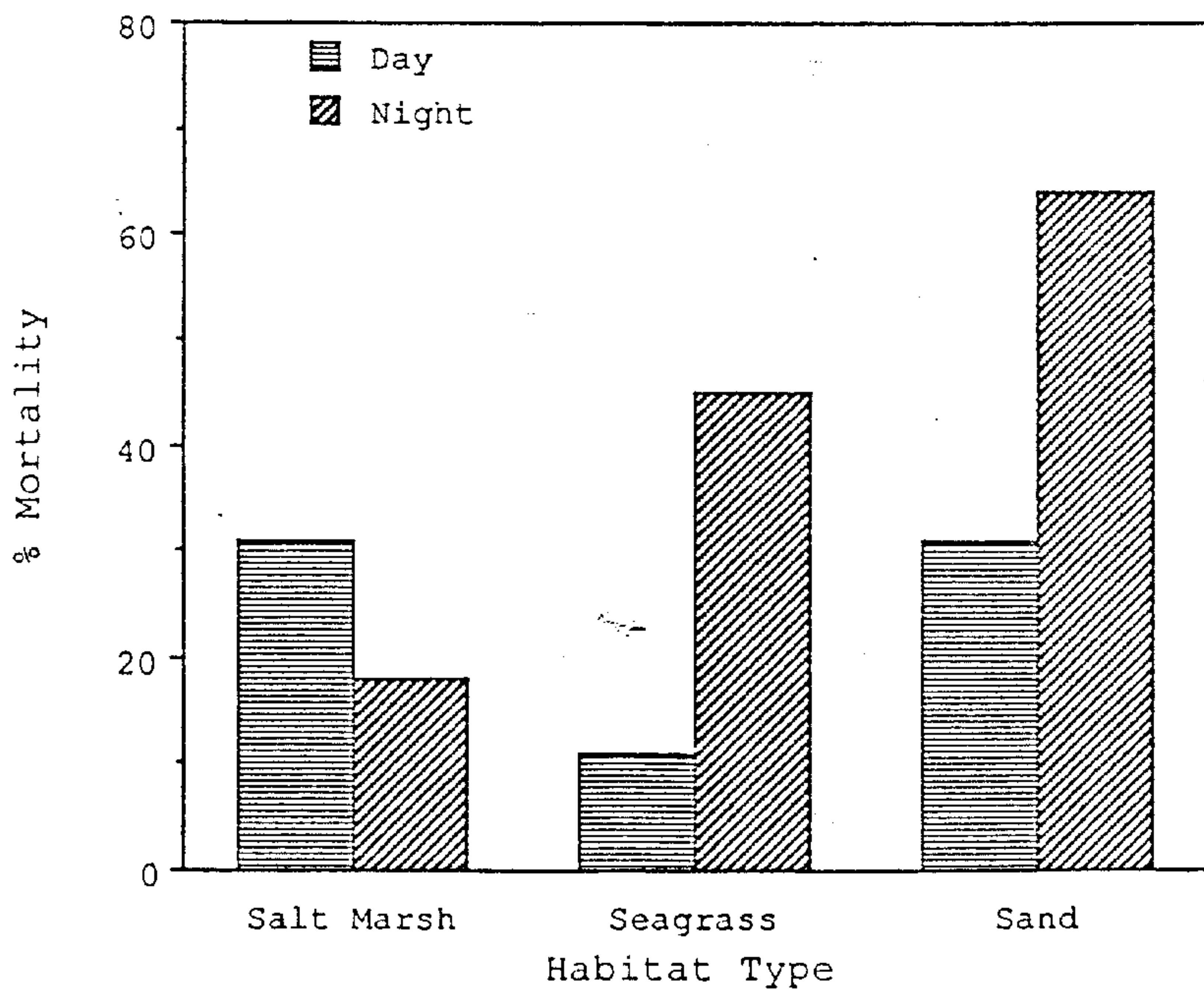
Figure 10. Predation by subadult blue crabs on juvenile blue crabs in
salt marsh, seagrass and sand habitats between day and night
predation experiments.

Table 9. Densities of seagrass used during predation experiments (mean and standard error).

Predator	Experiment Type	# Shoots/Core Mean	SE	# Leaves/Core Mean	SE	# Leaves/Shoot Mean
Pinfish	Daytime	58.4	5.49	179.4	11.70	3.1
	Nightime	79.7	6.08	195.3	15.43	2.5
Blue Crab	Daytime	70.0	3.92	90.2	6.53	1.3
	Nightime	53.6	8.11	62.4	9.79	1.2

predators were either active or passive. Active crab behaviors recorded included walking, feeding, swimming, fighting and burrowing. Crabs with passive behaviors were either burrowed or resting on top of the substrate or within vegetation. Within salt marsh and sand treatments, crabs exhibited similar amounts of active and passive behaviors (Table 10). Conversely, crab behaviors in seagrass treatments were almost exclusively active (Table 10).

Although no analyses were performed, juvenile crab activity during pinfish predation was greater at night than during the day in salt marsh and sand but not seagrass treatments (Table 11). During day predation, juveniles in all habitats exhibited passive behaviors and most were burrowed in the substrate (Table 11).

Pinfish

Pinfish predator activity in all treatments during both day and night experiments primarily involved rapid swimming (darting and attacking), hovering (staying in one place) and slow swimming behaviors (Table 12). Slow swimming and darting activities were greater during day hours than at night (Table 12). Hovering and searching activities were greater at night than during the day (Table 12).

Blue crab

Active behaviors of blue crab predators during day

Table 10. Total number of juvenile crab behaviors recorded in each habitat during 5-two minute daytime observation periods in the presence (P) and absence (A) of pinfish predators.

Habitat Type

Behavior Type	Salt Marsh		Seagrass		Sand	
	P	A	P	A	P	A
Active						
1. Walking	0	3	0	4	0	5
2. Feeding	0	10	0	12	0	5
3. Swimming	0	0	0	1	0	1
4. Fighting	0	0	0	3	0	0
5. Burrowing	0	1	0	0	0	1
Passive						
6. Burrowed	9	0	9	0	8	3
7. Resting	0	11	0	3	1	13
Totals	9	24	9	23	9	28

Table 11. Total number of juvenile blue crab behaviors recorded during 5-two minute observation periods in day (D) and night (N) pinfish predation experiments.

Habitat Type

Behavior Type	Salt Marsh		Seagrass		Sand	
	D	N	D	N	D	N
Active						
1. Walking	0	0	0	0	0	3
2. Feeding	0	2	0	2	0	1
3. Swimming	0	0	0	0	0	0
4. Fighting	0	0	0	0	0	1
5. Burrowing	0	0	0	0	0	0
Passive						
6. Burrowed	9	8	9	6	8	12
7. Resting	0	2	0	0	1	0
Totals	9	12	9	8	9	17

Table 12. Total number of pinfish predator behaviors recorded during 5-two
minute day and night observation periods (D = day, N = night).

Treatment

Behavior Type	Salt Marsh		Seagrass		Sand		Totals	
	D	N	D	N	D	N	D	N
1. Swimming	7	2	2	0	1	5	10	7
2. Attacking	0	0	0	0	1	1	1	1
3. Darting	0	0	0	0	1	0	1	0
4. Hovering	9	9	4	4	4	10	17	23
5. Searching	1	4	5	6	5	6	11	16

Table 13. Total number of blue crab predator behaviors recorded during
5-two minute day and night observation periods (D = day, N = night).

Treatment

Behavior Type	Salt Marsh		Seagrass		Sand		Totals	
	D	N	D	N	D	N	D	N
1. Walking	4	3	3	7	5	4	12	14
2. Feeding-vegetation	5	4	5	9	0	1	10	14
3. Feeding-crab prey	0	0	0	0	1	0	1	0
4. Swimming	1	0	1	0	1	2	3	2
5. Burrowing	0	0	0	0	0	0	0	0
6. Attacking	1	0	0	0	1	1	2	1
7. Burrowed-inactive	2	0	3	0	2	0	7	0
8. Resting on sand	4	4	2	6	6	9	12	19
9. Resting in vegetation	1	3	1	0	0	0	2	3

and night trials involved walking, swimming, feeding (picking at and digging within vegetation), burrowing and attacking movements (Table 13). In the seagrass treatment, blue crab predator activity was higher at night than during the day (Table 13). Conversely, in the salt marsh treatment, greater predator activity occurred during day hours (Table 13). In the sand treatment, predator activity occurring at night equalled that occurring during the day. Blue crab predators exhibiting passive behaviors were either partially burrowed or resting in vegetation or on top of the sand. Passive behaviors occurring during both day and night trials were similar in all habitats. Although incidentally recorded, juvenile crab activity during adult crab predation was higher during at night than during the day.

DISCUSSION

Feeding Experiments

The literature is replete with information on the effects of adult blue crab predation on benthic communities or on specific foods (Menzel and Hopkins 1955; Hamilton 1976; Young and Young 1978; Blundon and Kennedy 1982; Fort 1983; West and Williams 1986; Bisker and Castagna 1987). Numerous other studies also acknowledge the importance of predation in affecting the distribution and abundance of infaunal and small epifaunal invertebrates, especially in salt marsh and soft bottom communities (Virnstein 1977, 1979; van Dolah 1978; Peterson 1979; Holland et al. 1980; Nelson 1981b; Kneib and Stiven 1982; Virnstein et al. 1983; Kneib 1984; Summerson and Peterson 1984). However, few studies have analyzed the impact of predation by smaller crabs on benthic communities.

Results from gut content analyses substantiate spatial, seasonal and ontogenetic variations in blue crab diet (Laughlin 1982; Alexander 1986; Ryer 1987). Laughlin (1982), stated that in Apalachicola Bay, Florida, crabs smaller than 31 mm carapace width primarily consumed bivalves, plant matter, ostracods and detritus. Crabs between 31mm and 60 mm carapace width primarily consumed fishes, gastropods, plant matter and xanthid crabs. Crabs larger than 60 mm carapace width,

consumed more bivalves, fish, xanthid crabs and blue
crabs than either group one or two. Detritivory and
omnivory were present in all crab sizes, whereas
cannibalism was predominant only in larger crabs.
Similar findings were reported by Darnell (1959), Tagatz
(1968a) and Jaworski (1972). Other studies report
increased consumption of plant material by large blue
crabs (Darnell 1967; Cowper 1978; Laughlin 1982; Kitting
1984; van Montfrans et al. 1984; Alexander 1986).
Overall, these results indicate that the impact of
juvenile crabs on nursery habitat food resources may be
different from that of larger crabs. This would be
especially important during recruitment months.

In my study, the impact of juvenile crab feeding on
habitats was assessed both qualitatively and
quantitatively. During preliminary studies, I observed
juvenile crabs eating both plant and animal foods (i.e.
epiphytes, polychaetes, peracarids and molluscs).
Therefore, it was assumed that large reductions in the
abundance of these foods occurring during feeding
experiments were due to consumption by small crabs.

Plant foods

During preliminary experiments, cores of salt marsh
and seagrass vegetation were used to test the impact of
juvenile crab feeding on plant material within each
vegetated habitat. However, epifaunal and infaunal foods

were also associated with each core. It became difficult to insure that plant material was the only type of food being eaten. Epiphytes from salt marsh and seagrass habitats were then isolated. On Spartina culms, epiphytes were mostly blue green algae. They formed a relatively thin covering and constituted only a small fraction of the total biomass. This made reductions in epiphyte biomass difficult to detect. Halodule leaves, on the other hand, were heavily epiphytized with mostly green algae. Some sessile benthic hydroids and bryozoans may also have been present in very low numbers. Morgan and Kitting (1984), noted that within a Halodule grassbed along the southwest Texas coast, epiphytes constituted approximately 40% of the total biomass present. In my preliminary experiments, reductions in Halodule epiphyte biomass were easily detected both by observation and measurement. Therefore, Halodule epiphytes were chosen in preference to those on Spartina culms for testing feeding by blue crabs.

Washing of individual seagrass leaves appeared to remove all visible small animals present. Therefore, with the exception of microorganisms and a few sessile benthic hydroids and bryozoans, plants were the only food present in this experiment. In several beakers, after epiphytes were eaten, actual leaf material was consumed. But this appeared to be the exception more than the rule.

Feces and exuviae present in the bottom of treatment beakers were signs of successful growth from feeding. At the end of the experiment, four crabs had increased in width by 2-3 mm.

When leaves in treatments with crabs were compared to those in controls, their weights were significantly lower. This reduction in leaf weight was mostly due to the consumption of epiphytes by crabs. However, in three of the treatment beakers, partial seagrass leaf as well as epiphyte consumption also occurred. In addition, when beakers were initially designated as either experimental treatments or controls, an error was made. Instead of each category having 26 beakers, 25 beakers were designated as experimental treatments and 27 beakers were designated as controls. In spite of this error, a significant reduction plant biomass did occur in this experiment.

Other animals including mollusks, amphipods, isopods, decapods, echinoderms and fishes have been shown to derive nutrition from epiphytic material (Zimmerman et al. 1979; Gleason and Zimmerman 1984; Thayer et al. 1984; van Montfrans et al. 1984). Kitting (1984) noted that more epiphytic material was consumed by gastropods than green leaves or detritus.

Summary

The results obtained from my feeding experiment

showed that juvenile blue crabs also fed on epiphytes.
However, because Spartina epiphytes were not included in
the experiment, the comparative value of the two epiphyte
food sources is not known. Nevertheless, these results
support findings of large amounts of plant materials in
juvenile blue crab stomach contents (Darnell 1959; Tagatz
1968a; Laughlin 1982; Alexander 1986). They further
emphasize the importance of plant material in the diet of
juvenile blue crabs.

Animal foods

In my study, natural abundances of epifaunal and
infaunal foods occurring in microcosms without crabs were
compared among salt marsh, seagrass and sand habitats.
Differences in prey between habitats were largely that of
abundance rather than species composition. Epifaunal and
infaunal abundances were substantially higher in
abundance in vegetated habitats when compared to
nonvegetated habitats. Highest overall abundances of
animal foods occurred in the seagrass habitat.

Within all habitats, and especially seagrass,
polychaetous annelids constituted the largest proportion
of animal abundance and species number. Streblospio
benedicti, Capitella capitata and Mediomastus ambiseta
were analyzed because of their large numbers and small
size. Both factors increased their potential as foods
for small crabs. Furthermore, in my preliminary

experiments, these species were readily consumed when offered alone as food to juvenile crabs.

S. benedicti was the most abundant polychaete in each habitat. This opportunistic species is both a suspension and surface deposit feeder. It lives in ephemeral tubes of fine grain particles near the sediment-water interface (Rader 1984; Levin 1986). Holland et al. (1980), states that species with these characteristics are more susceptible to predation by epibenthic predators. In my preliminary experiments, this polychaete was also observed to be common among the seagrass epiphytes, a food source readily consumed by small crabs. Its high abundance during late fall and winter months corresponds to seasonally high numbers of juvenile blue crabs observed in Christmas Bay nursery habitats during the same time period (Santos and Simon 1974; Fort 1983; Thomas et al. in press). These factors further increased S. benedicti's susceptibility to predation by juvenile blue crabs. When abundances of S. benedicti in habitat treatments with crabs were analyzed, reduction in their numbers had occurred in both vegetated habitats, but not significantly.

C. capitata and M. ambiseta were second and third in abundance with numbers higher in either vegetated habitat than in sand. These species were most abundant in the seagrass habitat. As opportunistic burrowing deposit

feeders, they live within the upper 2-3 mm of sediment (Young and Young 1978). These species were also eaten, but their numbers were not significantly reduced. Annelids as a group were eaten by juvenile crabs. However, they were not significantly reduced in abundance (at α = 0.05) in any nursery habitat. Some of these results may also have been due to natural variability occurring in the distributions of these animals among the three habitats. The results in general indicate that Streblospio benedicti, Capitella capitata and Mediomastus ambiseta are eaten by small crabs, but only to a minor extent.

Abundances of peracarids, (tanaids, amphipods, isopods, mysids and cumaceans) were significantly different in each habitat. High abundances in the salt marsh habitat were predominantly due to the presence of the tanaid, Hargeria rapax. As an epibenthic tube dweller, this species is often attached to the bases of plants, detritus and tubes of other animals (Heard 1982). H. rapax feeds on benthic diatoms, ostracods and gammaridean amphipods (Rader 1984). In my study, its abundance was significantly higher in the salt marsh than sand or seagrass. This species has been documented as a common constituent of salt marsh and seagrass habitats (Heard 1982; Sheridan and Livingston 1983; Kneib 1984; Rader 1984)). Lewis and Stoner (1983) and Virnstein et

al. (1983), noted that H. rapax abundances were higher in pure stands of Thalassia and in mixed stands of Thalassia, Halodule and Syringodium than in sand habitats. However, in my experiments, H. rapax was low in abundance in both Halodule and sand habitats.

Consumption of H. rapax by juvenile blue crabs occurred only in the salt marsh treatment, but was not significant (at $\alpha = 0.05$). Other studies have documented significant reductions in the abundance of H. rapax within seagrass habitats. Virnstein et al. (1983) stated that this species increases in density inside predator exclusion cages within seagrass habitats. Nelson (1981b), states that H. rapax was significantly reduced in numbers within Halodule predator inclusion cages during predation by adult blue crabs. Low abundances of tanaids within seagrass and sand habitats in my treatment microcosms made reductions in numbers hard to detect.

Consumption of amphipods by blue crabs has been previously reported (Tagatz 1968a; Laughlin 1982; Stoner 1982). The most abundant species in my experiment were Gammarus mucronatus, Cymadusa compta, Grandidierella sp., Corophium sp. and Ampelisca sp. They are all reported as dominant species within both seagrass and salt marsh habitats (Young and Young 1978; Virnstein et al. 1983; Lewis and Stoner 1983; Sheridan and Livingston 1983; Fredette and Diaz 1986). As generalist feeders, G.

mucronatus and C. compta feed on macroalgae, microalgae and detritus (Zimmerman et al. 1979). C. compta is tubiculous, spending part of its time in shelters constructed from mucous and fine particles, whereas G. mucronatus is free living, found on portions of seagrass blades where epiphytic algae are most common (Stoner 1982; Morgan and Kitting 1984). Grandidierella sp. lives in tubes attached to shells, wood and other bottom substrata (Nelson 1979b; Sheridan 1979; Heard 1982). Members of this genus feed on small particulate detritus and epibenthic diatoms (Zimmerman et al. 1979). Such habitat-related food requirements were reflected in the distribution patterns of G. mucronatus, C. compta and Grandidierella sp. in Christmas Bay. During my experiment, the abundance of each species was similar in both seagrass and salt marsh habitats but was significantly lower in sand habitats.

Each species was eaten by small crabs in both seagrass and salt marsh habitats, to different degrees. G. mucronatus was eaten in both vegetated habitats. Higher numbers of Grandidierella sp. were eaten by small crabs in seagrass habitats than salt marsh habitats. Fredette and Diaz (1986), state that because of its feeding activities among seagrass epiphytes, G. mucronatus may be an important prey item for juvenile and adult fish and decapod crustaceans. Young and Young

(1977,1978), speculate that because of its high densities within predator exclusion cages, Grandidierella sp. may also be an important component of seagrass trophic dynamics. They also state that this species may normally be cropped too fast by predators to be adequately sampled. In my study, greater numbers of C. compta were eaten in salt marsh habitats than in seagrass habitats. However, increases in its abundance within seagrass predator exclusion cages have also been documented (Young and Young 1977).

Corophium sp. were most abundant in salt marsh habitats, unlike Ampelisca sp., which were most abundant in seagrass habitats. Both are tube-dwelling and utilize suspension/filtration methods for obtaining food. Corophium sp. was reduced in abundance in both vegetated habitats. Ampelisca sp. was reduced in abundance only in the seagrass habitat. These results could also be reflecting natural variations in their distributions among the vegetated habitats.

Differences in the reduction of amphipod abundances cannot be attributed to increased juvenile blue crab foraging efficiencies in Spartina when compared to Halodule; amphipods in both habitats were eaten. Tube-dwelling and infaunal amphipods do have a protective advantage with respect to both invertebrate and vertebrate predators (Nagle 1968). Therefore, one could

predict that after predation, infaunal amphipods would be highest in abundance followed by epifaunal tube dwellers and epibenthic species (Nelson 1979a). During my study, as expected, epifaunal free-living species were depleted and infaunal species were not. However, not all tube dwelling species were eaten and certain tube dwellers were eaten more than others in the same habitat. Tube structure and protective body coloration did vary among the amphipod species. Its camouflaging effect may have been more pronounced in one habitat than another. Amphipod feeding behaviors may have rendered certain species more vulnerable to predation. Some amphipod species may feed among epiphytes where crabs are feeding as opposed to others that may feed more secretively.

Isopod species were low in abundance within all habitats. Edotea montosa appeared only sporadically within both seagrass and salt marsh habitats. Its natural abundances were so low that reductions due to crab feeding were hard to detect. Erichsonella sp. occurred only in the seagrass habitat. However, its natural abundances were higher and reductions by juvenile blue crabs were detected. This genus has been documented by Virnstein et al. (1983) as a dominant species occurring in seagrasses. Young and Young (1977) state that Erichsonella increased in abundance inside seagrass predator exclusion cages. Alexander (1986) has

documented the presence of isopods within blue crab stomach contents. Such documentation indicates their possible use as a food item for juvenile blue crabs. All remaining peracarids (mysids and cumaceans) occurred in very low numbers and were not analyzed.

In general, more peracarids were eaten by juvenile blue crabs. This "preference" in feeding may have been related to an increased need for additional chitin utilized during rapid juvenile crab growth periods. Polychaete chitin in general is present only in parapodial setae or mouth structures. It is different in structure to that used by crustaceans during cuticle formation and therefore may not be as valuable to juvenile crabs.

Use of molluscs as food for blue crabs has been widely reported (Menzel Hopkins 1955; Darnell 1959; Tagatz 1968a; Hamilton 1976; Vince et al. 1976; Blundon and Kennedy 1982; Laughlin 1982; Alexander 1986; Lipcius and Hines 1986; West and Williams 1986; Bisker and Castagna 1987; Ryer 1987). Studies that cite specific use of bivalves and gastropods by juvenile blue crabs include Darnell (1959) and Laughlin (1982). Amygdalum papyrium, Diastoma varium, and Tellina sp. were all generally low in abundance in all habitats. Their numbers were lower in experimental microcosms than in controls. This could have been due to crab feeding. It

may also have been a reflection of natural variability occurring among the habitats. A. papyrium was the only species that was significantly reduced in numbers. This occurred in the seagrass habitat. A. papyrium has been documented as a dominant infaunal species occurring in salt marsh and seagrass habitats (Heard 1982; Virnstein et al. 1983). Although significantly higher in abundance within the salt marsh habitat, D. varium was only incidentally eaten. Other studies have documented its occurrence and consumption by predators in seagrass. It small in size and is usually found among seagrass leaves feeding on epiphytic material. Young and Young (1978) state that as densities of Halodule decreased, D. varium abundances also decreased. Young and Young (1977) have also documented increased D. varium abundances occurring inside seagrass predator exclusion cages. Tellina sp. was highest in abundance in the sand habitat. However, they were eaten in all habitats. This could have also been just a reflection of variable distribution among the habitats. Virnstein et al. (1983) documented the occurrence of this species in sand habitats but classified it as "nondominant".

Because of the occurrence of crab escapes during this feeding experiment, it is possible that the actual densities of animals recovered from within experimental microcosms may have been even lower than observed.

Unfortunately, the timing of crab escapes from microcosms and the relative impact on fauna is not known.

Summary

Results of feeding experiments confirmed that juvenile blue crabs fed on plant foods. Animal foods were eaten differently within each habitat. Highest overall abundance of plant and animal foods as well as highest feeding rates occurred in the seagrass habitat.

Peracarids (tanaids, amphipods and isopods) and molluscs were fed on most. In the salt marsh habitat, the amphipod, _Cymadusa_ _compta_, was the only species significantly reduced as a result of feeding by juvenile crabs. The tanaid, _Hargeria_ _rapax_ was also eaten but not significantly depleted. In the seagrass habitat, _Gammarus_ _mucronatus_, _Grandidierella_ sp. _Erichsonella_ sp. and _Amygdalum_ _papyrium_ were significantly reduced in numbers. Smaller polychaetous annelids were occasionally eaten in each habitat and may only be incidental dietary items for small blue crabs.

Although juvenile crabs appear to eat the same general types of foods as larger crabs, many of their foods are smaller in size. Because of the presence of complex rhizome structures associated with high densities of vegetation, the foraging abilities of larger crabs are often decreased (Orth 1977). Therefore, they are usually restricted to areas of low vegetation density for

feeding. However, because juvenile crabs are smaller in size, they are able to exploit all types of structured habitats for feeding. This creates a certain degree of niche separation which may contribute to increased juvenile crab survival.

Predation Experiments

Structural complexity in the form of plant biomass present in estuarine habitats has been shown to increase the amount of habitable living space for newly recruited juvenile fish and invertebrate species.(Hooks et al. 1976; Heck and Wetstone 1977; Heck and Orth 1980a; Stoner 1980b; Lewis and Stoner 1983; Zimmerman et al. 1984; Minello and Zimmerman 1985; Orth and van Montfrans in press). Leaf canopies or stands of grass dampen current and wave motion and decrease turbidity by trapping suspended organic particles (Heck and Wetstone 1977; Kikuchi and Peres 1977). Root and rhizome mats associated with vegetation stabilize the sediment and increase the uniformity of characteristics such as grain size (Kikuchi and Peres 1977; Stoner 1980b).

Vegetative leaf and root structure also provide a refuge from predation for juveniles by impeding predator foraging abvilties, especially for those that visually search or dig for their food (O'Gower and Wacasey, 1967; Taylor and Lewis, 1970; Vince et al., 1976; Orth 1977; Minello and Zimmerman 1983; Orth et al. 1984). However,

the type of protection provided varies with the type of vegetation present, its shoot and root density and its leaf morphology (Vince et al. 1976; Van Dolah 1978; Heck and Orth 1980a; Stoner 1980c; Leber 1985). Water turbidity has also been shown to affect predation rates within habitats (Minello et al. 1986).

Orth (1977) states that non-vegetated habitats are often unstable environments due to the constant exposure of substrate sediments to currents and wave action. Thus, lower animal densities observed in such habitats may be due in part to postlarval resuspension and export and the inability of newly recruited larvae to settle.

My experiments compared the degree of protection provided to juvenile blue crabs by two different types of vegetation, Spartina alterniflora and Halodule wrightii and by bare sand during predation by two species that commonly occurred during peak crab recruitment months: pinfish, Lagodon rhomboides and subadult blue crabs, Callinectes sapidus. Pinfish represented abundant fish predators that occupy the water column. Using visual, tactile and chemical means of locating their prey, they captured prey through swimming and striking movements. Subadult blue crabs represented benthic predators that rely on mechanical, visual and chemical means of locating their prey. They captured prey through walking, swimming, grabbing and shredding movements.

Densities of S. alterniflora used in these
experiments approximated those observed throughout fall
recruitment months at Christmas Bay (Thomas et al. in
press). Halodule densities used in the pinfish
experiment reflected those observed during the early
fall. Densities used in the subadult blue crab
experiment reflected those observed during late fall
recruitment months. Results from pinfish and subadult
blue crab predation experiments may be best understood
when discussed in context with observations of juvenile
crab behaviors while in the absence of predators.
Predator-prey interactions that occurred during
subsequent observation trials will also be discussed.

Juvenile blue crab

Previous experimental results had indicated that
juvenile crabs as little as 5 mm (carapace width) smaller
than others were likely to be cannibalized. Furthermore,
Darnell (1959), Tagatz (1968a) and Laughlin (1982) had
all reported findings of small blue crab remains in the
stomachs of larger crabs. In juvenile blue crab
observation experiments using ten crabs that were each 10
mm in carapace width, no significant mortalities due to
cannibalism or other natural causes occurred in seagrass,
salt marsh or sand habitats. Factors promoting
cannibalism such as reduced amounts of preferred food
items, crowding of individuals and the promotion of

physiological and/or psychological stress (Fox 1975), were apparently reduced in my treatment tanks. Because the experiment was short in duration, plenty of food was available. The presence of vegetation within salt marsh and seagrass treatments allowed crabs to separate themselves, reducing the effects of crowding. Individuals within the sand tanks compensated for the lack of a vegetative refuge by burrowing into the sand at various distances from each other.

In the absence of predators, juvenile crabs in the salt marsh treatment were located around the base of each clump of Spartina. They spent most of the observation time picking at epiphytic algae and/or epifauna on the culms. Occasionally, crabs climbed upward between the grass blades and stalks. Juveniles in seagrass treatments spent the majority of the observation time associated with vegetation, either at the base or tips of the leaves picking off epiphytic material. Occasionally, several crabs moved between seagrass cores. Crabs in the sand treatment spent half of the observation time walking around the tank, picking food off the substrate. The remaining half was spent resting on top of the substrate or burrowed to eye level. Crabs in all tanks were active both night and day, feeding and moving about on the substrate surface.

Juvenile crab response to the addition of either

predator was similar within each habitat. Crabs on
Spartina culms immediately wedged themselves into smaller
crevices between leaves. All crabs remained hidden
within the vegetation or burrowed in the substrate.
Crabs that were situated at the tips of seagrass leaves
moved downward towards the thicker parts of each clump.
Many burrowed in the sand amongst the leaves within each
core. Similar observations were made by Orth and van
Montfrans (1982) and Wilson et al. (1987). A different
"microhabitat shift" was documented for Tozeuma
carolinense (Main 1987). During predation, Tozeuma moved
from lower areas of seagrass towards the leaf tips, where
they gained protection in the leaf canopy. When
predators were introduced into my sand treatments, all
small crabs previously on the surface burrowed. Crabs
previously burrowed up to eye level, burrowed even deeper
into the substrate. In several instances, when predators
were on opposite sides of treatment tanks, two to three
small crabs moved about with both chelae outstretched and
open.

Pinfish

During day pinfish predation, juveniles in all
habitats remained inactive or burrowed. Kitting (1984)
states that day residence near the sediment surface
suggests the importance of dense grass cover during
daylight predation pressure. During day trials, pinfish

in all treatments swam erratically back and forth over
the substrate. Predation pressure seemed to be
intensified in sand and salt marsh habitats but remained
the same in seagrass habitats. Only one attack was
actually observed during a day observation trial. It
occurred in the sand treatment. Upon release, a pinfish
spotted a partially burrowed crab and attacked it. The
crab did manage to escape and burrow deeper into the sand
after which it could not be seen. Juvenile crab
mortalities were significantly higher in the sand
treatment than either vegetated treatment. Similar
mortality results have been reported by Coen et al.
(1981), Minello and Zimmerman (1985) and Wilson et al.
(1987).

At night, several crabs in each habitat began
feeding but were still guarded. Similar field
observations of increased nocturnal activity were made by
Daud (1979) and Morgan and Kitting (1984). Stein
(1979), states that because foraging involves prey
activity that can elicit predator attack, many prey
species feed only during periods when predators are least
efficient.

Pinfish have been documented as visual feeders that
actively feed only during daylight hours (Minello and
Zimmerman 1983). Juvenile crabs in my experiment were
most active during the time when pinfish were least

efficient as predators. Juvenile crab mortalities did occur during night trials, but were not significantly different from those occurring during day trials. During the night trial, they were significantly higher in the sand habitat than salt marsh or seagrass habitats.

Although pinfish visual acuity was decreased during night predation trials, other senses may have been used to find prey. In the sand treatment, pinfish picked at the substrate during feeding. During these "picking" behaviors, small amounts of sand were picked up and filtered through their gills. As a result, numerous pit-type areas were visible on the substrate in each treatment tank at the end of each trial. This indicated that pinfish may have been using tactile mechanisms for food capture. Carr et al. (1976), documented an induced feeding behavior by pinfish that responded to blue crab extract released into tank water. He states that pinfish responded by increasing their swimming movements, eventually striking at the source of the extract. Thus chemosensory feeding mechanisms may also play an important role during feeding at night or during the day in naturally turbid estuarine environments.

One pinfish attack was observed during night trials in the sand treatment. A crab was attacked several times and was finally eaten. Similar observations of pinfish attack inefficiency were documented by Coen et al (1981)

and Minello and Zimmerman (1983). At the end of both day and night predation trials, no juvenile crabs were visible in these treatment tanks. Only after totally emptying the tanks of all sand were juveniles recovered. This indicated that juvenile crabs rely heavily on burrowing deep within nonvegetated substrate as an escape response in the presence of predators.

Juvenile blue crabs in the Spartina alterniflora treatment suffered intermediate numbers of mortalities, which were generally greater during the day than at night. While pinfish swam up, down and around clumps of Spartina searching for food, juvenile crabs remained hidden between leaves and the stem on each Spartina culm. Juvenile crab mortalities may have been lower at night due to lowered vision capabilities of pinfish predators. The mortalities that did occur may have been related to increased juvenile crab feeding activities.

Fish in seagrass treatments swam near the substrate, often very close to the base of seagrass cores where juvenile crabs were burrowed. None of the fish were observed to move through the seagrass cores. Juvenile crab mortalities in this treatment were low and generally unchanged between day and night hours. The intertwined structure of high density heavily epiphytized seagrass leaves may have hidden the crabs from pinfish. This may not be the case for other fish predators known to feed on

blue crabs, such as toadfish which use ambush tactics or redfish, which use other sensory mechanisms to obtain prey (Boothby and Avault 1971; Wilson et al. 1982; Minello and Zimmerman 1983; Gibbons and Castagna 1985; Wilson et al. 1987).

Although lower, mortalities occurring the seagrass treatment were not significantly different from those occurring in the salt marsh treatment. Within treatment variability of natural seagrass core densities used within each tank may have contributed to the inability to statistically separate the degree of protection offered by this habitat. On the other hand, this result may be correct. Stoner (1982) states that of all seagrass species tested, <u>Halodule wrightii</u> provided the least amount of protection to amphipods during pinfish predation.

Trends in the protective capacity of the three habitats during pinfish predation definitely occurred. As expected, the bare sand habitat provided the lowest degree of protection to juvenile crabs. The salt marsh habitat provided an intermediate degree of protection. Although not significant, seagrass structure provided more protection than salt marsh structure. The degree of its protection offered was consistently high during both day and night pinfish predation.

Blue crab

During blue crab predation, the highest percent of juvenile crab mortalities occurred in sand treatment. This may have been due to the lack of root and rhizome structure present which then increased the crab predator's foraging efficiency (Orth 1977; Virnstein et al. 1983). Juvenile crab mortalities were almost equivalent in salt marsh and seagrass treatments. With the exception of the salt marsh treatment, predator activity was greater at night than during the day. The same pattern of activity was observed for juvenile crabs.

During both day and night predation, blue crab predators in all treatments spent most of their time digging. In the salt marsh treatment, predators would dig down into the substrate at the base of each clump of Spartina and pull up root material. In several instances, large crabs were observed in a vertical position, with their claws totally buried and their eyes touching the sand. Any vegetation uncovered would then be eaten. On two occasions, digging activity resulted in the uprooting of an entire clump of Spartina. In this treatment, crab predators were more active during daylight hours. During this time period, the salt marsh may provide greater protection from predators to larger blue crabs than either seagrass or sand. Crab predators in this treatment seemed to be more intent on digging

into the substrate for vegetative root structure, detritus and possible infaunal organisms that would be present in a field situation, than searching for things hidden up in or on Spartina leaves. These results support findings by Ryer (1987), who states that crabs collected from Chesapeake Bay salt marshes contained larger proportions of plant-derived detrital material than animal material in their stomachs.

One observation was made in this treatment of an attack on a juvenile crab by a crab predator. The juvenile crab was buried in the substrate at the base of a Spartina culm where a crab predator was digging. When disturbed, the juvenile crab swam up into the water column and the larger crab pursued. The juvenile crab was able to escape. It appeared to be "in the way" of the digging process that was going on. High juvenile crab mortalities occurring in this treatment during day hours may have been the result of such predator-prey encounters.

Mortalities were lower at night, but not significantly. This may have been due to reduced predator foraging efficiencies in the salt marsh at night. Crab predator activities were equally divided among walking/feeding type movements and resting. In addition, juvenile crabs were feeding among Spartina leaves instead of burrowing into the substrate. As a

result, they were not as vulnerable to predation.

Juvenile crab mortalities sustained in seagrass treatments were significantly higher at night than during the day. At night, crab predators spent most of the observation time feeding and moving all around the tank. They constantly uprooted vegetation by digging within and around each core. As a result, numerous juvenile crabs were disturbed. They swam up into the water and were generally pursued by predators. Crab predators also pulled Halodule leaves down to their mouths, to consume epiphytic material. Orth (1977) observed similar behaviors from blue crabs feeding on Zostera epibiota. At the end of each of my night trials, a large proportion of vegetation was uprooted and floating on the water surface. Despite all the predator activity occurring at night, juvenile crabs actively fed in the leaf canopy on remaining epiphytes.

During the course of my experiments (spring to fall), biomass on seagrass leaves in Christmas Bay was increased due to recruitment of large numbers of sessile hydroids. At the same time, leaf densities were decreased. This defoliation of Halodule occurs regularly in Christmas Bay during the late fall and may be responsible, in part, for decreased juvenile crab densities observed at this time. In my experiment, this defoliation decreased the protective cover available to

juvenile crabs, resulting in increased mortalities. Nelson (1979b), hypothesized that a "threshold effect" of plant densities existed after which protection from predation was significantly increased. This effect was also reported by Heck and Thoman (1981), who state that a threshold density of artificial seagrass was required before predator effectiveness was significantly reduced. It may have been that this threshold density was not reached in seagrass tanks used during these predation experiments.

During day hours, predator activity was suppressed. Similar amounts of time were spent feeding and resting either on top of the sand, in vegetation or partially buried. Juvenile crab mortalities were also lower in this habitat during daylight hours than either salt marsh or sand habitats.

Mortalities occurring in the sand treatments were higher at night than during the day. During both day and night hours, crab predators constantly moved around digging into the substrate. At night, juvenile crabs were also active, but were guarded. Two attacks were observed in this treatment, one during day hours and the other at night. Larger crabs had been moving about the tanks when juvenile crabs were spotted. In both instances, predators chased, captured and consumed the juveniles. At the end of each night trial, a majority of

the crab predators in each treatment were partially buried in the substrate. They may have been satiated from feeding.

During blue crab predation, significant interactions occurred between the type of habitat and time of day. At night, which corresponds to peak predator and prey feeding periods, the bare sand habitat provided the least amount of protection, followed by seagrass and salt marsh habitats. During the day, several of the trends were reversed. The seagrass habitat provided the most protection to juvenile crabs. Protection provided by the salt marsh habitat equalled that provided by the sand habitat. This result was surprising. The presence of vegetation should have reduced predator efficiency to some degree. However, even though all physical factors (eg. temperature, salinity, light and vegetation density) were held constant, results from each of the salt marsh treatments tanks were highly variable. The source of this variability may have been the predators themselves.

Summary

During both predation experiments, comparative degrees of protection provided to juvenile blue crabs by salt marsh, seagrass and bare sand habitats were assessed. Two totally different predators known to eat juvenile crabs were used to make this comparison. To isolate the effect of habitat type as the primary factor

controlling juvenile crab survival, predation occurring within and among the habitat treatments had to be standardized. This was accomplished, in part, by feeding juvenile blue crabs to both types of predators to form a search image, and then starving the predators 24 hours prior to the experiment. Enclosing both predators and prey in habitat treatment tanks increased the rate of encounters and intensified predation.

As expected, the degree of protection provided by the vegetated habitats varied with type of vegetation present and its density. Protection provided by all habitats varied with the method of prey capture used and the time of day. Bare sand provided the least protection during both day and night predation by pinfish. It provided the least amount of protection from blue crab predators at night but was similar to that provided by salt marsh during the day.

Spartina alterniflora provided an intermediate degree of protection between that of sand and seagrass during day and night pinfish predation. During daytime blue crab predation this habitat provided protection that equalled that of sand. At night, it offered the greatest amount of protection from blue crabs.

Even though its densities varied between the two types of predation experiments, Halodule wrightii provided the greatest amount of protection from both

predators during the day. The high grass densities used at night during pinfish predation provided great amounts of protection to juvenile crabs. Lower densities used during blue crab predation provided limited protection to juvenile crabs.

CONCLUSION

During fall recruitment months at Christmas Bay, juvenile crabs (during daytime hours) were in highest abundance in <u>Halodule wrightii</u>, followed by <u>Spartina alterniflora</u> and bare sand habitats (Thomas et al. in press). To better understand some of the factors controlling such distribution patterns, laboratory experiments were conducted that assessed the comparative value of food and protection provided to juvenile blue crabs by these co-occurring habitats. The working hypothesis was that the seagrass habitat provided more food and protective benefits than either salt marsh or sand.

Feeding experiments indicated that juvenile crabs differentially ate foods occurring within the three habitats. Epifaunal and infaunal foods were higher in abundance within both vegetated habitats when compared to sand. The highest overall abundance and utilization of foods by juvenile blue crabs occurred within the seagrass habitat followed by the salt marsh and sand habitats. Within the seagrass habitat, juvenile crabs fed on epiphytic material that occurred on seagrass leaves. Animals significantly reduced in abundance were the epifaunal amphipods <u>Gammarus mucronatus</u>, <u>Grandidierella</u> sp., the isopod <u>Erichsonella</u> sp. and the infaunal mollusk <u>Amygdalum papyrium</u>.

Within the _Spartina alterniflora_ habitat, juvenile crabs fed on the tanaid _Hargeria rapax_ and the tubiculous amphipod _Cymadusa compta_. One gastropod species, _Diastoma varium_, and two amphipod species, _Corophium_ sp. and _Ampelisca_ sp., were incidentally eaten in both vegetated habitats. _Tellina_ sp. was the only mollusk species incidentally eaten in the sand habitat.

Predation experiments conducted within each of the three habitats indicated that the degree of protection provided to juvenile crabs varied with the mode of prey capture used by various predators, and time of day. _Halodule wrightii_ provided the greatest degree of protection to juvenile crabs during day predation by pinfish and blue crab predators. However, during night hours, its protection varied with its density.

Spartina alterniflora provided an intermediate degree of protection during both day and night predation by pinfish, and during night predation by blue crabs. Blue crab predators were more active in this habitat during the day, resulting in higher juvenile crab mortalities. The sand habitat provided the least amount of protection during both day and night trials with pinfish predators and during night trials with subadult blue crabs.

The working hypothesis that seagrass would provide the greatest food and protective benefits can only be

partially accepted. Even though food abundance and utilization was greatest in this habitat, the degree of its protection varied with leaf density, the type of predator used, and the time of day. When these results are considered in context with juvenile blue crab distribution patterns observed in Christmas Bay (Thomas et al. in press), it appears that higher numbers of juveniles present within seagrass habitats during fall recruitment months may be a response to increased amounts of available food as well as protection from an abundant fish predator.

The intermediate density of juvenile crabs observed within the salt marsh habitat at Christmas Bay may be more related to decreased protection from predators by _Spartina_ structure than to the abundance of food. Low juvenile crab densities observed in the sand habitat are probably the result of high predation pressure and low food availability. This study further documents the value of seagrass beds and salt marshes within the northwestern Gulf as juvenile crab nurseries. Further research needs to be conducted that tests the effects of pinfish (small and large sizes), blue crabs and other predators on protection provided by different species of seagrass and salt marsh vegetation as well as nonvegetated substrates to juvenile blue crabs while varying light and turbidity levels.

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APPENDICES

Appendix 1.   Core data from feeding experiments.

Salt Marsh, Control (SPC):

Polychaetes: SPC	1	2	3	4	5	6	7	8	Total
Amphicteis gunneri	1	0	0	0	0	1	0	0	2
Aricidea philbinae	0	0	0	0	0	0	0	0	0
Aricidea taylori	0	0	0	0	0	0	0	0	0
Axiothella mucosa	0	0	0	0	0	0	0	0	0
Capitella capitata	4	8	4	2	2	35	8	33	96
Chone spp.	0	0	0	1	1	0	2	1	5
Cirrophorus lyra	0	0	0	0	0	0	0	0	0
Diopatra cuprea	0	0	0	0	0	0	0	0	0
Drilonereis longa	0	0	0	0	0	0	0	0	0
Eumida sanguinea	0	3	1	2	0	2	1	0	9
Glycera americana	0	0	0	0	0	0	0	0	0
Goniada maculata	0	0	0	0	0	0	0	0	0
Goniada teres	0	0	0	0	0	0	0	0	0
Goniadella sp. A	0	0	0	0	0	0	0	0	0
Heteromastus filiformis	1	0	4	10	4	0	8	0	27
Jasmineira sp.	0	0	0	0	0	0	0	0	0
Laeonereis culveri	0	0	0	0	0	0	0	0	0
Lumbrineris verrilli	0	0	0	0	0	0	0	0	0
Mediomastus ambiseta	0	1	0	0	0	4	0	0	5
Melinna maculata	0	0	0	0	0	0	0	0	0
Neanthes succinea	4	0	35	0	21	20	48	19	147
Nereis lamellosa	0	0	0	0	0	1	0	0	1
Nematonereis hebes	0	0	0	0	0	0	1	0	1
Polydora ligni	1	1	0	0	0	1	0	1	4
Polydora cf. socialis	0	0	0	0	0	0	0	0	0
Protula sp.	0	0	0	1	0	0	0	0	1
Sabella microphthalma	0	0	0	3	0	2	3	0	8
Scolelepis texana	0	0	0	0	0	0	0	0	0
Spiochaetopterus costarum	0	0	0	0	0	0	0	0	0
Spiophanes bombyx	0	0	0	0	0	0	0	0	0
Streblospio benedicti	31	102	61	0	32	58	19	110	413
Tharyx marioni	0	0	0	0	0	0	0	0	0
Unidentified worms	1	0	0	0	0	0	0	0	1
--------Totals----------	43	115	105	19	60	124	90	164	720

Amphipods: SPC	1	2	3	4	5	6	7	8	Total
Ampelisca sp.	0	0	0	0	0	0	0	0	0
Caprella sp.	0	1	0	0	0	0	0	0	1
Corophium sp.	0	5	2	0	3	5	3	2	20
Cymadusa compta	0	2	17	4	2	3	10	0	38
Elasmopus levis	0	0	0	0	0	0	2	0	2
Gammarus mucronatus	2	0	6	0	1	2	17	24	52
Grandidierella sp.	3	1	2	4	4	9	1	7	31
--------Totals----------	5	9	27	8	10	19	33	33	144

Tanaids: SPC	1	2	3	4	5	6	7	8	Total
Hargeria rapax	117	117	19	5	103	160	137	200	858

Appendix 1 (continued)

Salt Marsh, Control (SPC):			Core Replicate						
	1	2	3	4	5	6	7	8	Total
Isopods: SPC									
Edotea montosa	0	0	1	0	0	0	0	0	1
Erichsonella attenuata	0	0	0	0	0	0	0	0	0
--------Totals----------	0	0	1	0	0	0	0	0	1
Molluscs: SPC									
Acteocina canaliculata	0	0	0	0	0	0	0	0	0
Amygdalum papyrium	0	0	1	1	0	0	3	0	5
Anadara transversa	0	0	1	0	0	0	0	0	1
Diastoma varium	0	0	6	2	2	2	2	0	14
Laevicardium mortoni	0	0	0	0	0	0	0	0	0
Littorina irrorata	0	0	0	0	0	0	0	0	0
Lucina pectinata	0	0	0	0	0	0	0	0	0
Modiolus americanus	0	0	0	0	0	0	0	0	0
Mulinia lateralis	0	0	0	1	0	0	1	0	2
Nassarius vibex	0	0	0	0	0	0	0	0	0
Neritina virginea	0	0	0	0	·0	0	0	0	0
Rictaxis punctostriatus	0	0	0	0	0	0	0	0	0
Sayella sp.	0	0	0	0	0	0	0	0	0
Sayella cf. livida	0	0	0	0	0	0	0	0	0
Tellina sp.	0	0	0	1	0	0	0	0	1
--------Totals----------	0	0	8	5	2	2	6	0	23
Others: SPC									
Crabs	0	0	0	1	0	0	0	0	1
Cumaceans	0	0	0	0	0	0	0	0	0
Mysids	0	0	0	0	0	0	0	0	0
Nemerteans	0	0	0	0	1	1	0	3	5
Oligochaetes	0	3	1	0	0	5	2	7	18
--------Totals----------	0	3	1	1	1	6	2	10	24

Salt Marsh, Experimental (SPE):
Polychaetes: SPE

	1	2	3	4	5	6	7	8	Total
Amphicteis gunneri	0	0	1	0	0	0	1	0	2
Aricidea philbinae	0	0	0	0	0	0	0	0	0
Aricidea taylori	0	0	0	0	0	0	0	0	0
Axiothella mucosa	3	0	0	0	1	3	0	0	7
Capitella capitata	9	7	7	12	1	4	15	11	66
Chone spp.	0	1	0	1	0	2	7	0	11
Cirrophorus lyra	0	0	0	0	0	0	0	0	0
Diopatra cuprea	0	0	0	0	0	0	0	0	0
Drilonereis longa	0	0	0	0	0	0	0	0	0
Eumida sanguinea	3	0	0	0	0	0	0	1	4
Glycera americana	0	0	0	0	0	0	0	0	0
Goniada maculata	1	0	0	0	0	0	0	0	1
Goniada teres	0	0	0	0	0	0	0	0	0
Goniadella sp. A	0	0	0	0	0	0	0	0	0

Appendix 1 (continued)
Salt Marsh, Experimental (SPE):

	1	2	3	4	5	6	7	8	Total
Polychaetes: SPE (continued)									
Heteromastus filiformis	17	10	0	1	9	6	0	0	43
Jasmineira sp.	0	0	0	0	0	1	0	0	1
Laeonereis culveri	0	0	0	0	0	0	1	0	1
Lumbrineris verrilli	0	0	0	0	0	0	0	0	0
Mediomastus ambiseta	0	0	3	0	0	1	1	0	5
Melinna maculata	0	0	0	0	0	0	0	0	0
Neanthes succinea	55	24	9	23	28	42	29	13	223
Nereis lamellosa	0	0	0	0	0	0	0	0	0
Nematonereis hebes	0	0	0	1	0	0	0	0	1
Polydora ligni	0	0	1	2	0	0	0	0	3
Polydora cf. socialis	0	0	0	0	0	0	0	0	0
Protula sp.	0	0	0	0	0	0	0	0	0
Sabella microphthalma	4	7	0	1	1	5	4	1	23
Scolelepis texana	0	0	0	0	0	0	0	0	0
Spiochaetopterus costarum	0	0	0	0	0	0	0	0	0
Spiophanes bombyx	0	0	0	0	.0	0	0	0	0
Streblospio benedicti	29	21	55	58	21	39	64	14	301
Tharyx marioni	0	0	0	0	0	0	0	0	0
Unidentified worms	0	1	0	0	0	1	0	0	2
--------Totals----------	121	71	76	99	61	104	122	40	694
Amphipods: SPE									
Ampelisca sp.	1	0	0	0	1	0	0	0	2
Caprella sp.	0	0	0	0	0	0	0	0	0
Corophium sp.	5	1	0	2	0	2	1	0	11
Cymadusa compta	0	0	0	2	0	2	0	1	5
Elasmopus levis	0	0	0	0	0	1	0	0	1
Gammarus mucronatus	6	0	0	0	0	0	1	0	7
Grandidierella sp.	5	4	1	0	1	6	2	2	21
--------Totals----------	17	5	1	4	2	11	4	3	47
Tanaids: SPE									
Hargeria rapax	81	15	21	52	7	53	74	21	324
Isopods: SPE									
Edotea montosa	0	0	0	0	0	0	0	0	0
Erichsonella attenuata	0	0	0	0	0	0	0	0	0
--------Totals----------	0	0	0	0	0	0	0	0	0
Molluscs: SPE									
Acteocina canaliculata	0	0	0	0	0	0	0	0	0
Amygdalum papyrium	1	1	0	0	0	0	0	0	2
Anadara transversa	0	0	0	0	0	1	0	0	1
Diastoma varium	0	0	0	2	1	5	0	1	9
Laevicardium mortoni	0	0	0	0	0	0	0	0	0
Littorina irrorata	0	0	0	0	0	0	0	0	0
Lucina pectinata	0	0	0	0	0	0	0	0	0
Modiolus americanus	0	0	0	0	0	0	0	0	0

Core Replicate

Appendix 1 (continued)

Salt Marsh, Experimental (SPE):   Core Replicate

	1	2	3	4	5	6	7	8	Total
Molluscs: SPE (continued)									
Mulinia lateralis	0	0	0	0	0	0	0	0	0
Nassarius vibex	0	0	0	0	0	0	0	0	0
Neritina virginea	0	0	0	1	0	0	0	0	1
Rictaxis punctostriatus	0	1	0	0	0	0	0	0	1
Sayella sp.	0	0	0	0	0	0	0	0	0
Sayella cf. livida	0	0	0	0	0	0	0	0	0
Tellina sp.	0	0	0	0	0	0	0	0	0
--------Totals-----------	1	2	0	3	1	6	0	1	14
Others: SPE									
Crabs	0	0	0	0	0	0	0	0	0
Cumaceans	0	0	0	0	0	0	0	0	0
Mysids	0	0	0	0	0	0	0	0	0
Nemerteans	0	1	0	1	0	0	0	1	3
Oligochaetes	2	1	3	1	0	5	28	5	45
--------Totals-----------	2	2	3	2	0	5	28	6	48
Seagrass, Control (SGC):									
Polychaetes: SGC									
Amphicteis gunneri	0	0	0	0	0	0	0	0	0
Aricidea philbinae	2	0	1	0	0	0	1	0	4
Aricidea taylori	1	0	2	0	0	0	0	1	4
Axiothella mucosa	2	2	0	0	0	2	0	0	6
Capitella capitata	7	11	22	16	18	6	10	29	119
Chone spp.	5	1	7	1	1	3	3	1	22
Cirrophorus lyra	0	0	0	0	0	0	0	0	0
Diopatra cuprea	0	0	0	0	0	0	0	0	0
Drilonereis longa	0	0	0	0	0	0	0	0	0
Eumida sanguinea	1	0	0	1	1	0	0	1	4
Glycera americana	0	0	1	0	0	0	0	0	1
Goniada maculata	0	0	0	0	0	0	0	0	0
Goniada teres	0	0	0	0	0	0	0	1	1
Goniadella sp. A	1	0	0	0	0	0	0	0	1
Heteromastus filiformis	0	0	0	0	1	0	0	0	1
Jasmineira sp.	2	3	3	6	6	5	1	3	29
Laeonereis culveri	0	0	0	0	0	0	0	0	0
Lumbrineris verrilli	1	1	1	0	0	1	0	0	4
Mediomastus ambiseta	0	0	0	0	0	0	0	0	0
Melinna maculata	12	17	15	31	4	9	30	32	150
Neanthes succinea	1	0	0	0	0	0	1	0	2
Nereis lamellosa	5	3	3	1	5	3	3	6	29
Nematonereis hebes	0	0	0	0	0	0	0	0	0
Polydora ligni	0	0	0	0	0	0	0	0	0
Polydora cf. socialis	1	0	5	2	0	2	0	0	10
Protula sp.	0	0	0	0	0	0	0	0	0
Sabella microphthalma	0	0	0	0	0	0	0	0	0
Scolelepis texana	0	0	0	0	1	0	1	0	2

Appendix 1 (continued)

Seagrass, Control (SGC):

	1	2	3	4	5	6	7	8	Total
Polychaetes: SGC (continued)									
Spiochaetopterus costarum	0	0	0	0	0	0	0	0	0
Spicphanes bombyx	0	0	0	0	0	0	0	0	0
Streblospio benedicti	0	0	0	1	0	0	0	0	1
Tharyx marioni	398	369	388	455	268	299	372	599	3148
Unidentified worms	16	9	0	0	1	3	0	0	29
--------Totals----------	455	416	448	514	306	333	422	673	3567
Amphipods: SGC									
Ampelisca sp.	1	0	5	1	9	0	5	3	24
Caprella sp.	0	0	0	0	0	0	0	0	0
Corophium sp.	0	0	0	0	0	0	0	1	1
Cymadusa compta	6	0	1	3	6	1	1	6	24
Elasmopus levis	0	0	1	0	0	0	0	0	1
Gammarus mucronatus	1	0	5	1	5	2	0	1	15
Grandidierella sp.	2	3	5	3	5	1	2	4	25
--------Totals----------	10	3	17	8	25	4	8	15	90
Tanaids: SGC									
Hargeria rapax	7	3	0	0	2	3	2	0	17
Isopods: SGC									
Edotea montosa	0	1	1	0	0	0	0	2	4
Erichsonella attenuata	2	0	3	2	2	2	1	0	12
--------Totals----------	2	1	4	2	2	2	1	2	16
Molluscs: SGC									
Acteocina canaliculata	0	0	0	0	0	0	0	0	0
Amygdalum papyrium	3	1	1	0	1	0	1	0	7
Anadara transversa	0	0	0	0	0	0	0	0	0
Diastoma varium	0	1	0	1	3	0	0	3	8
Laevicardium mortoni	0	0	0	0	0	0	0	0	0
Littorina irrorata	0	0	0	1	0	0	0	0	1
Lucina pectinata	0	0	0	0	0	0	0	0	0
Modiolus americanus	0	0	0	0	0	0	0	0	0
Mulinia lateralis	0	0	0	0	0	0	0	0	0
Nassarius vibex	0	0	0	0	0	0	0	0	0
Neritina virginea	1	1	0	0	0	0	0	0	2
Rictaxis punctostriatus	0	0	0	0	0	0	0	0	0
Sayella sp.	0	0	0	0	0	0	1	0	1
Sayella cf. livida	0	0	1	0	0	0	0	0	1
Tellina sp.	0	0	8	0	2	0	0	0	10
--------Totals----------	4	3	10	2	6	0	2	3	30
Others: SGC									
Crabs	0	0	0	0	1	1	0	0	2
Cumaceans	1	1	0	0	1	0	0	2	5
Mysids	1	0	0	0	0	0	0	0	1
Nemerteans	0	0	0	1	0	0	0	0	1

Appendix 1 (continued)

Seagrass, Control (SGC):				Core	Replicate				
	1	2	3	4	5	6	7	8	Total
Others: SGC (continued)									
Oligochaetes	5	0	0	18	0	12	8	43	86
--------Totals-----------	7	1	0	19	2	13	8	45	95

Seagrass, Experimental (SGE):
Polychaetes: SGE

	1	2	3	4	5	6	7	8	Total
Amphicteis gunneri	0	0	0	0	0	0	0	0	0
Aricidea philbinae	1	1	2	3	0	1	2	0	10
Aricidea taylori	1	0	0	3	0	1	2	0	7
Axiothella mucosa	0	5	2	2	0	1	0	0	10
Capitella capitata	9	3	8	7	5	12	12	15	71
Chone spp.	1	3	0	1	0	4	1	14	24
Cirrophorus lyra	0	0	0	0	0	0	0	0	0
Diopatra cuprea	0	0	0	0	0	0	1	0	1
Drilonereis longa	0	0	0	0	0	0	0	0	0
Eumida sanguinea	0	0	0	0	0	0	0	0	0
Glycera americana	0	0	0	0	0	0	1	0	1
Goniada maculata	0	0	0	0	0	0	0	0	0
Goniada teres	0	0	0	0	0	0	0	0	0
Goniadella sp. A	0	0	0	0	0	0	0	0	0
Heteromastus filiformis	6	13	1	2	4	7	2	0	35
Jasmineira sp.	0	0	0	0	0	0	0	0	0
Laeonereis culveri	1	1	0	0	0	0	0	0	2
Lumbrineris verrilli	0	0	0	0	0	0	0	0	0
Mediomastus ambiseta	3	16	3	5	3	24	18	25	97
Melinna maculata	0	0	0	1	0	0	0	0	1
Neanthes succinea	1	3	0	2	4	4	0	2	16
Nereis lamellosa	0	0	0	0	0	0	0	0	0
Nematonereis hebes	0	0	0	0	0	0	0	0	0
Polydora ligni	0	3	1	1	0	1	0	0	6
Polydora cf. socialis	0	1	0	0	0	0	0	0	1
Protula sp.	0	0	0	0	0	0	0	0	0
Sabella microphthalma	0	0	0	0	0	0	0	0	0
Scolelepis texana	0	0	0	1	0	0	0	0	1
Spiochaetopterus costarum	0	0	0	0	0	0	0	0	0
Spiophanes bombyx	0	0	0	0	0	0	0	0	0
Streblospio benedicti	366	408	334	420	280	403	273	388	2872
Tharyx marioni	0	9	3	6	0	2	2	0	22
Unidentified worms	389	466	354	454	296	460	314	444	3177
--------Totals-----------									

Amphipods: SGE

	1	2	3	4	5	6	7	8	Total
Ampelisca sp.	4	6	0	3	4	0	2	0	19
Caprella sp.	0	0	0	0	0	0	0	0	0
Corophium sp.	0	0	0	0	0	0	0	0	0
Cymadusa compta	2	0	0	0	2	3	0	0	7
Elasmopus levis	0	0	0	0	0	0	0	0	0
Gammarus mucronatus	2	0	0	0	0	1	0	0	3

Appendix 1 (continued)

Seagrass, Experimental (SGC):

Amphipods: SGE (continued)	Core Replicate								
	1	2	3	4	5	6	7	8	Total
Grandidierella sp.	0	1	0	0	0	3	2	0	6
--------Totals----------	9	9	3	7	11	13	11	8	35

Tanaids: SGE									
Hargeria rapax	1	3	9	0	0	4	0	0	17

Isopods: SGE									
Edotea montosa	0	0	0	0	0	1	0	0	1
Erichsonella attenuata	0	2	0	0	0	0	0	0	2
--------Totals----------	0	2	0	0	0	1	0	0	3

Molluscs: SGE									
Acteocina canaliculata	0	0	1	0	0	1	0	0	2
Amygdalum papyrium	0	0	0	0	0	0	0	0	0
Anadara transversa	0	0	0	0	0	0	0	0	0
Diastoma varium	1	0	0	0	0	1	1	0	3
Laevicardium mortoni	0	0	0	0	0	0	0	0	0
Littorina irrorata	0	0	0	0	0	0	0	0	0
Lucina pectinata	0	0	0	0	0	0	0	0	0
Modiolus americanus	0	0	1	0	0	0	0	0	1
Mulinia lateralis	0	0	0	0	0	0	0	0	0
Nassarius vibex	1	0	0	0	0	0	0	0	1
Neritina virginea	0	0	0	0	0	0	0	0	0
Rictaxis punctostriatus	0	0	0	0	0	1	0	0	1
Sayella sp.	0	0	0	0	0	0	0	0	0
Sayella cf. livida	0	0	0	0	0	0	0	0	0
Tellina sp.	0	1	0	0	0	1	0	0	2
--------Totals----------	2	1	2	0	0	4	1	0	10

Others: SGE									
Crabs	0	1	0	0	0	0	0	1	2
Cumaceans	0	0	0	0	0	0	0	0	0
Mysids	0	0	0	0	0	0	0	0	0
Nemerteans	0	0	0	0	0	1	0	0	1
Oligochaetes	5	18	2	2	7	9	16	0	59
--------Totals----------	5	19	2	2	7	10	16	1	62

Sand, Control (SC):

Polychaetes: SC									
Amphicteis gunneri	0	0	0	0	0	0	0	0	0
Aricidea philbinae	0	1	0	0	1	0	0	1	3
Aricidea taylori	0	0	0	0	0	0	0	0	0
Axiothella mucosa	0	0	0	0	0	0	0	0	0
Capitella capitata	0	1	2	0	0	2	0	0	5
Chone spp.	0	0	0	0	2	0	0	0	2
Cirrophorus lyra	0	0	0	0	0	0	0	0	0
Diopatra cuprea	0	0	0	0	0	0	0	0	0

Appendix 1 (continued)

Sand, Control (SC):	Core Replicate								
	1	2	3	4	5	6	7	8	Total
Polychaetes: SC (continued)									
Drilonereis longa	0	0	0	0	0	0	0	0	0
Eumida sanguinea	0	0	0	0	0	0	0	0	0
Glycera americana	0	0	0	0	0	0	0	0	0
Goniada maculata	0	0	0	0	0	0	0	0	0
Goniada teres	0	0	0	0	0	0	0	0	0
Goniadella sp. A	0	0	0	0	0	0	0	0	0
Heteromastus filiformis	9	11	4	7	5	6	0	2	44
Jasmineira sp.	0	0	0	0	0	0	0	0	0
Laeonereis culveri	1	0	0	0	0	1	0	0	2
Lumbrineris verrilli	0	0	0	0	0	0	0	0	0
Mediomastus ambiseta	1	0	0	0	1	0	0	0	2
Melinna maculata	0	1	0	0	0	0	0	0	1
Neanthes succinea	0	0	0	0	0	0	0	0	0
Nereis lamellosa	0	0	0	0	0	0	0	0	0
Nematonereis hebes	0	0	0	0	0	0	0	0	0
Polydora ligni	0	2	1	0	0	0	0	0	3
Polydora cf. socialis	0	0	0	0	0	0	0	0	0
Protula sp.	0	0	0	0	0	0	0	0	0
Sabella microphthalma	0	0	0	0	0	0	0	0	0
Scolelepis texana	0	0	1	1	1	1	0	0	4
Spiochaetopterus costarum	1	0	0	0	0	0	0	0	1
Spiophanes bombyx	0	0	0	0	0	0	0	0	0
Streblospio benedicti	79	83	84	39	73	15	0	57	430
Tharyx marioni	1	0	0	0	0	0	0	2	3
Unidentified worms	0	0	0	2	1	1	0	0	4
--------Totals----------	92	99	92	49	84	26	0	62	504
Amphipods: SC									
Ampelisca sp.	1	0	0	0	0	0	0	0	1
Caprella sp.	0	0	0	0	0	0	0	0	0
Corophium sp.	0	0	0	0	0	0	0	0	0
Cymadusa compta	0	0	0	0	0	0	0	0	0
Elasmopus levis	0	0	0	0	0	0	0	0	0
Gammarus mucronatus	0	0	0	0	0	0	0	0	0
Grandidierella sp.	1	0	0	0	0	0	0	0	1
--------Totals----------	2	0	0	0	0	0	0	0	2
Tanaids: SC									
Hargeria rapax	19	4	4	1	3	0	0	19	50
Isopods: SC									
Edotea montosa	0	0	0	0	0	0	0	0	0
Erichsonella attenuata	0	0	0	0	0	0	0	0	0
--------Totals----------	0	0	0	0	0	0	0	0	0
Molluscs: SC									
Acteocina canaliculata	0	0	0	1	0	1	0	0	2
Amygdalum papyrium	0	0	0	0	0	0	0	0	0

Appendix 1 (continued)

Sand, Control (SC):	Core Replicate								
	1	2	3	4	5	6	7	8	Total
Molluscs: SC (continued)									
Anadara transversa	0	0	0	0	0	0	0	0	0
Diastoma varium	0	0	0	0	0	0	0	0	0
Laevicardium mortoni	0	0	0	0	0	0	0	0	0
Littorina irrorata	0	0	0	0	0	0	0	0	0
Lucina pectinata	0	0	0	0	0	0	0	0	0
Modiolus americanus	0	0	0	0	0	0	0	0	0
Mulinia lateralis	0	0	0	0	0	0	0	0	0
Nassarius vibex	0	0	0	0	0	0	0	0	0
Neritina virginea	0	0	0	0	0	0	0	0	0
Rictaxis punctostriatus	0	0	0	0	2	0	0	0	2
Sayella sp.	0	0	0	0	0	0	0	0	0
Sayella cf. livida	0	0	0	0	0	0	0	0	0
Tellina sp.	0	0	0	0	2	1	0	0	3
--------Totals----------	0	0	0	1	4	2	0	0	7
Others: SC									
Crabs	0	0	0	0	0	0	0	0	0
Cumaceans	1	0	0	0	1	0	0	1	3
Mysids	0	0	0	0	0	0	0	1	1
Nemerteans	0	0	0	0	0	0	0	0	0
Oligochaetes	2	5	2	2	8	0	0	1	20
--------Totals----------	3	5	2	2	9	0	0	3	24
Sand, Experimental (SE):									
Polychaetes: SE									
Amphicteis gunneri	0	0	0	0	0	0	0	0	0
Aricidea philbinae	2	0	0	1	1	0	0	0	4
Aricidea taylori	0	1	0	0	0	0	0	0	1
Axiothella mucosa	0	0	0	0	0	0	0	0	0
Capitella capitata	0	2	1	0	3	0	0	0	6
Chone spp.	0	0	0	0	0	0	0	0	0
Cirrophorus lyra	0	0	0	1	0	0	0	0	1
Diopatra cuprea	0	0	0	0	0	0	0	0	0
Drilonereis longa	0	0	1	0	0	0	0	0	1
Eumida sanguinea	0	0	0	0	0	0	0	0	0
Glycera americana	1	0	0	0	0	0	0	0	1
Goniada maculata	0	0	0	0	0	0	0	0	0
Goniada teres	0	0	0	0	0	0	0	0	0
Goniadella sp. A	0	0	0	0	0	0	0	0	0
Heteromastus filiformis	5	8	10	5	0	2	6	3	39
Jasmineira sp.	0	0	0	0	0	0	0	0	0
Laeonereis culveri	1	0	0	0	1	1	0	0	3
Lumbrineris verrilli	2	0	0	0	0	0	0	0	2
Mediomastus ambiseta	0	3	0	0	0	2	1	1	7
Melinna maculata	0	0	0	0	0	0	0	0	0
Neanthes succinea	0	0	0	0	0	0	0	0	0
Nereis lamellosa	0	0	0	0	0	0	0	0	0

Appendix 1 (continued)

Sand, Experimental (SE):

	1	2	3	4	5	6	7	8	Total
				Core	Replicate				
Polychaetes: SE (continued)									
Nematonereis hebes	0	0	0	0	0	0	0	0	0
Polydora ligni	0	0	0	0	3	0	0	0	3
Polydora cf. socialis	0	0	0	0	0	0	0	0	0
Protula sp.	0	0	0	0	0	0	0	0	0
Sabella microphthalma	0	0	0	0	0	0	0	0	0
Scolelepis texana	0	1	0	1	2	0	0	0	4
Spiochaetopterus costarum	1	0	0	0	0	0	0	0	1
Spiophanes bombyx	0	0	0	0	1	0	0	0	1
Streblospio benedicti	99	122	18	67	73	23	106	0	508
Tharyx marioni	0	0	0	0	0	2	1	0	3
Unidentified worms	0	0	0	0	0	0	1	0	1
--------Totals----------	111	137	30	75	84	30	115	4	586
Amphipods: SE									
Ampelisca sp.	0	0	4	0	0	0	0	0	4
Caprella sp.	0	0	0	0	0	0	0	0	0
Corophium sp.	0	0	0	0	1	0	0	0	1
Cymadusa compta	0	0	0	0	0	0	0	0	0
Elasmopus levis	0	0	0	0	0	0	0	0	0
Gammarus mucronatus	0	0	0	0	0	0	0	0	0
Grandidierella sp.	0	0	0	0	0	0	1	0	1
--------Totals----------	0	0	4	0	1	0	1	0	6
Tanaids: SE									
Hargeria rapax	17	6	1	4	6	19	14	0	67
Isopods: SE									
Edotea montosa	0	0	1	0	0	0	0	0	1
Erichsonella attenuata	0	0	0	0	0	0	0	0	0
--------Totals----------	0	0	1	0	0	0	0	0	1
Molluscs: SE									
Acteocina canaliculata	0	0	0	0	0	0	0	0	0
Amygdalum papyrium	0	0	0	0	0	0	0	0	0
Anadara transversa	0	0	0	0	0	0	0	0	0
Diastoma varium	0	0	0	0	0	0	0	0	0
Laevicardium mortoni	0	0	0	0	1	0	0	0	1
Littorina irrorata	0	0	0	0	0	0	0	0	0
Lucina pectinata	0	0	0	0	0	0	1	0	1
Modiolus americanus	0	0	0	0	0	0	0	0	0
Mulinia lateralis	0	0	0	0	0	0	0	0	0
Nassarius vibex	0	0	0	0	0	0	0	0	0
Neritina virginea	0	0	0	0	0	0	0	0	0
Rictaxis punctostriatus	1	0	0	0	0	0	0	0	1
Sayella sp.	0	0	0	0	0	0	0	0	0
Sayella cf. livida	0	0	0	0	0	0	0	0	0
Tellina sp.	0	0	0	0	0	0	0	0	0
--------Totals----------	1	0	0	0	1	0	1	0	3

Appendix 1 (continued)
Sand, Experimental (SE):

Others: SE	1	2	3	4	5	6	7	8	Total
Crabs	0	0	0	0	0	0	0	0	0
Cumaceans	0	0	0	0	0	0	0	0	0
Mysids	0	0	0	0	0	0	0	0	0
Nemerteans	0	0	0	0	0	0	0	0	0
Oligochaetes	6	3	31	1	2	0	3	5	51
--------Totals-----------	6	3	31	1	2	0	3	5	51

Core Replicate (column headers 1–8, Total)

Appendix 2.
Juvenile blue crab percent mortality during predation
by pinfish.

Trial	Time	Habitat	Mortality
1	Day	Sand	100
1	Day	Sand	80
1	Day	Sand	60
1	Day	Sand	20
1	Day	Sand	90
1	Day	Marsh	80
1	Day	Marsh	40
1	Day	Marsh	20
1	Day	Marsh	10
1	Day	Marsh	20
1	Day	Grass	20
1	Day	Grass	0
1	Day	Grass	0
1	Day	Grass	0
1	Day	Grass	0
1	Day	Control	10
1	Day	Control	10
1	Day	Control	0
1	Day	Control	0
1	Day	Control	0
2	Day	Sand	90
2	Day	Sand	80
2	Day	Sand	70
2	Day	Sand	30
2	Day	Sand	10
2	Day	Marsh	40
2	Day	Marsh	30
2	Day	Marsh	20
2	Day	Marsh	10
2	Day	Marsh	0
2	Day	Grass	60
2	Day	Grass	20
2	Day	Grass	10
2	Day	Grass	0
2	Day	Grass	0
2	Day	Control	0
2	Day	Control	0
2	Day	Control	0
2	Day	Control	0
2	Day	Control	0
1	Night	Sand	80
1	Night	Sand	80
1	Night	Sand	80
1	Night	Sand	0
1	Night	Sand	0
1	Night	Marsh	50
1	Night	Marsh	40
1	Night	Marsh	30
1	Night	Marsh	10

Appendix 2 (Continued)

TRIAL	TIME	Habitat	Mortality
1	Night	Marsh	0
1	Night	Grass	20
1	Night	Grass	20
1	Night	Grass	10
1	Night	Grass	0
1	Night	Grass	0
1	Night	Control	0
1	Night	Control	0
1	Night	Control	0
1	Night	Control	0
1	Night	Control	0
2	Night	Sand	90
2	Night	Sand	70
2	Night	Sand	50
2	Night	Sand	40
2	Night	Sand	0
2	Night	Marsh	30
2	Night	Marsh	20
2	Night	Marsh	20
2	Night	Marsh	0
2	Night	Marsh	0
2	Night	Grass	50
2	Night	Grass	10
2	Night	Grass	0
2	Night	Grass	0
2	Night	Grass	0
2	Night	Control	0
2	Night	Control	0
2	Night	Control	0
2	Night	Control	0
2	Night	Control	0

Appendix 3.
Juvenile blue crab percent mortality during predation
by subadult blue crabs.

Trial	Time	Habitat	Mortality
1	Day	Sand	20
1	Day	Sand	30
1	Day	Sand	0
1	Day	Sand	10
1	Day	Sand	50
1	Day	Marsh	0
1	Day	Marsh	10
1	Day	Marsh	90
1	Day	Marsh	90
1	Day	Marsh	90
1	Day	Grass	0
1	Day	Grass	0
1	Day	Grass	0
1	Day	Grass	10
1	Day	Grass	0
1	Day	Control	0
1	Day	Control	0
1	Day	Control	0
1	Day	Control	0
1	Day	Control	0
2	Day	Sand	30
2	Day	Sand	70
2	Day	Sand	10
2	Day	Sand	60
2	Day	Sand	30
2	Day	Marsh	20
2	Day	Marsh	10
2	Day	Marsh	0
2	Day	Marsh	0
2	Day	Marsh	0
2	Day	Grass	40
2	Day	Grass	40
2	Day	Grass	10
2	Day	Grass	10
2	Day	Grass	0
2	Day	Control	0
2	Day	Control	0
2	Day	Control	0
2	Day	Control	0
2	Day	Control	0
1	Night	Sand	70

Appendix 3 (Continued)

TRIAL	TIME	Habitat	Mortality
1	Night	Sand	60
1	Night	Sand	70
1	Night	Sand	70
1	Night	Sand	20
1	Night	Marsh	10
1	Night	Marsh	10
1	Night	Marsh	0
1	Night	Marsh	10
1	Night	Marsh	0
1	Night	Grass	80
1	Night	Grass	0
1	Night	Grass	20
1	Night	Grass	50
1	Night	Grass	70
1	Night	Control	0
1	Night	Control	0
1	Night	Control	0
1	Night	Control	0
1	Night	Control	0
2	Night	Sand	100
2	Night	Sand	50
2	Night	Sand	100
2	Night	Sand	60
2	Night	Sand	40
2	Night	Marsh	30
2	Night	Marsh	10
2	Night	Marsh	10
2	Night	Marsh	10
2	Night	Marsh	90
2	Night	Grass	60
2	Night	Grass	60
2	Night	Grass	40
2	Night	Grass	40
2	Night	Grass	30
2	Night	Control	0
2	Night	Control	0
2	Night	Control	0
2	Night	Control	0
2	Night	Control	0

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